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The Effect of Injury in Imitation of Hail Damage on the Development of the Corn Plant

By John C. Eldredge

AGRICULTURAL EXPERIMENT STATION
IOWA STATE COLLEGE OF AGRICULTURE
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FARM CROPS SUBSECTION

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SUMMARY

1. Total leaf removal (stripping) at weekly intervals, from four-leaf to first tassel stages, caused reduction in yield in almost direct proportion to the percentage of the leaves unrolled at the time the injury was inflicted. The yield reduction ranged from 9 percent during early June to 100 percent about July 20, at the pre-tassel stage, decreasing gradually after the completion of fertilization and ending with a 5 percent reduction in yield on Sept. 7 when the corn was nearly mature.

2. Severe shredding at weekly intervals, which removed about 50 percent of the unrolled leaves, caused a reduction in yield of 2 percent for the first 2 weeks in June. Yields dropped gradually at each weekly period until the low point, with a 50 percent reduction, was reached at the pre-tassel stage, and then gradually rose, ending with a 7 percent reduction on Sept. 7.

3. Removal of one-third and two-thirds of the leaves followed the same trends as shredding and stripping. There was very slight reduction for the first 2 weeks, then a drop in yields to a low point of 30 percent and 70 percent reduction, respectively, at the critical tasseling-silking stage, and a gradual increase to 8 and 12 percent reduction on Sept. 7.

4. Removal of half of each leaf at the pre-tassel stage, the full tassel stage and the milk stage reduced yields 27 percent, 33 percent and 13 percent, respectively.

5. Minor leaf injuries which were designed to upset the elaboration and translocation of synthesized plant food did not result in significant decreases in yield.

6. Severe bruising of stalks and ears a week before the tasseling stage reduced the yield 20 percent which increased to a 35 percent reduction at the full tassel stage. Yields gradually rose to a 6 percent reduction on Sept. 7.

7. Severe bruising of stalks and ears and severe shredding of leaves reduced yields 64 percent a week before tasseling and 77 percent at the tasseling stage. Yields gradually rose to a 9 percent reduction on Sept. 7.

8. A comparison of shredding only, bruising only, and shredding and bruising for 1931 and 1932 shows that while shredding reduced yields 64 percent and bruising 35 percent at the critical tasseling period a combination of the two reduced yields only 13 percent more than shredding only.

9. Severe shredding of six different strains of corn at two critical periods did not result in significant differences in yield reduction for the different strains.

10. Severe drouth in 1930 caused moisture to become the limiting factor so that leaf and stalk injuries did not result in as great a decrease in yield as in normal seasons. In June, reduction in leaf area reduced transpiration and resulted in somewhat larger yields from the injured plots than from the checks.

11. Leaf and stalk injury at all stages of development resulted in little reduction in kernel development, as measured by bushel test weight, except where a very large proportion of the leaf area was removed either just preceding, during, or following the tasseling-silking period. Earlier in the season the size of the ears was reduced by leaf removal but the weight per bushel was nearly normal.

12. Bruising of the ears resulted in 2 to 3 percent of damaged kernels, which would cause the corn to grade No. 2. This is not important since corn seldom, if ever, grades better than No. 2 under farm conditions.

13. Injury during the rapidly developing period preceding the tasseling stage resulted in some increase in percentage of smutted plants, the number varying directly with the amount of smut occurring each year in uninjured corn. There was no relation between the type of injury and smut infection except in 1929 when bruising the ears just as silking began resulted in a decided increase in ear smut. This did not occur in any of the other seasons. No noticeable increase in other corn diseases resulted from any type of injury.

The Effect of Injury in Imitation of Hail Damage on the Development of the Corn Plant[1]

By John C. Eldredge[2]

The average annual damage from hail storms in Iowa, as reported by Reed (51) of the United States Weather Bureau, for the 8-year period, 1923 to 1930, was $4,513,760.00, or 1.15 percent of the average annual value of the crops of the state. An average of 35 percent of the townships annually reported hail. Reed suggests that undoubtedly the loss was greater than reported, as many storms, occurring early in the season, are forgotten the following spring when the township assessors collect the information. Olsen *et al.* (44) place Iowa in an intermediate position relative to the remainder of the United States on the basis of number of days with hail. The western three-fourths of the state is included with the Great Plains area, which is the great hail region of the United States. Only two limited areas in the Rocky Mountain region are more subject to hail.

Olsen estimated that the total hail insurance in force in 1919 in the United States was $560,000,000.00 and that almost four-fifths was written in the seven middle western states, Kansas, North Dakota, Iowa, South Dakota, Nebraska, Minnesota and Oklahoma, over one-half of the total being written in the first three.

Data compiled by Wagner (59) show that approximately 50 percent of the gross premium income of all state mutual insurance associations which insure against fire, tornado, windstorm, hail, auto and some miscellaneous coverages, comes from hail insurance, and that the losses paid amount to over 50 percent of such insurance. Wagner states that "it is estimated from insurance experience that your 'insurable chance for loss' if you live in Iowa is as follows: 1 in 200 chances to have buildings damaged by wind or tornado; 1 in 100 chances to have buildings damaged by fire; 1 in 6 chances to have growing crops damaged by hail. In 1928 one in four farmers carrying

[1] Project No. 349 of the Iowa Agricultural Experiment Station.

[2] The writer is indebted to Prof. H. D. Hughes and Dr. W. E. Loomis for their many helpful suggestions throughout the investigation, as well as for their helpful criticism of the manuscript; to Dr. A. A. Bryan and Prof. G. W. Snedecor for their suggestions as to statistical methods; and to his wife for assistance in computing and checking the data.

A study of the effect of various types of leaf injury on the rate of photosynthesis and translocation of carbohydrates was made in connection with the investigations reported in this bulletin. A complete presentation of this phase of the investigation is reported, together with the material in this bulletin, in a thesis entitled, "The Effect of Injury in Imitation of Hail Damage on the Development of Corn," by John C. Eldredge, Iowa State College Library. 1933.

hail insurance were paid a loss and in 1933 one-third of the farmers carrying insurance were hailed.'' Wagner estimates that from one-fourth to one-third of the farmers in Iowa carry hail insurance, the percentage varying in different parts of the state. The fact that hail seems to occur more frequently in some sections than in others probably accounts for this variation. In recent years the northern half of the state has had more hail than the southern.

Olsen (44) states that ''one of the most difficult problems in hail insurance is the adjustment of losses.'' Several reasons might be suggested to explain this difficulty. In the first place it is difficult to determine just how much damage has been done. Careful counts can be made of the proportion of injured and normal plants in a given area, but even then no one can say certainly, in many cases, how badly the individual plants are damaged. The portion of leaf area remaining, the extent of bruises on the stalk or ear, and the amount of recovery the plant will make, are some of the things which are difficult to determine accurately. Weather conditions later in the season often have an important effect on recovery after a hail storm and, of course, no accurate weather predictions can be made. High winds a few days after a hail storm frequently break over many bruised stalks which in another season, without the wind, would not have broken.

Probably one of the most important factors contributing to the difficulty in obtaining satisfactory loss adjustments is the lack of information on the physiology of plants by both adjuster and farmer. Many adjusters in the past have claimed that leaf damage was unimportant, holding that the plant obtained its nutrients from the soil and had normally more leaves than were needed. On the other hand, these same adjusters allowed total damage on bruised stalks the yield of which probably would not be reduced by as much as 20 percent. Farmers have insisted, also, that after a hail storm a field of corn or small grain would suffer an epidemic of smut or other disease, or that if 10 percent of the tassels were damaged the pollination would be poor and the yield consequently reduced. Injury by disease and mechanical injury by machinery and insects have been attributed to hail, and, likewise, hail injury has been attributed to these factors.

A quotation from Wagner's (59) report indicates the problems involved in hail injury. ''Another interesting ratio explains the need for experimentation in studying partial hail losses—only 1 in 200 losses exceeds 75 percent damage. So the great majority of losses vary from one percent to 75 percent damage. Little experimentation is needed to help understand total losses (except small grain which can seem totally de-

stroyed, yet stool out under favorable conditions and make part of a later crop) but the need of experimentation is recognized on the vast number of losses which are partial."

The foregoing observations indicate the need of investigating hail injury to crops. On the one hand we find crop losses, due to hail, of millions of dollars annually and a hail insurance business greater than all other forms of farm mutual insurance combined, while, on the other hand, there is a profound ignorance of plant response coupled with great uncertainty as to how seriously the plant is injured, or how successfully it can recover.

PREVIOUS STUDIES ON LEAF AND STALK INJURY

No reference in the literature has been found relative to the effect of stalk damage on the yield of corn, at least not as differentiated from leaf damage. Dungan (12 to 19 inclusive) has reported on several phases of his artificial hail injury investigations, but nearly all of these were concerned with leaf injury. He (12) inflicted what he terms "a light treatment" with a bundle of wires, shredding the leaves and bruising the stalks and ears slightly. This type of injury, given when the tassels were emerging, reduced the yield 4.3 percent, while a week later, when the corn was in tassel, with ear shoots but no silks showing, the same type of treatment reduced the yield 15.9 percent. Removal of all the leaf blades at the tassel stage reduced the yield 92.3 percent, while whipping with a wire brush in addition to leaf removal caused a 95.2 percent reduction in yield. Removal of all leaf blades from succeeding rows at 10-day intervals, from the time the corn was in full tassel to the soft dough stage, reduced yields in percentage of check as follows: 92.3, 95.5, 73.2, 54.4, 26.5, 16.9. This period extended from July 25 to Sept. 26.

Dungan states (14) that "quality of grain was markedly reduced by blade removal, especially after the silks had browned on 50 to 70 percent of the plants, or in the early milk stage. Blade removal in the early silk stage allowed the plants to adjust the size of the ear to the reduced photosynthetic area of the leaf and they produced grain of almost normal quality. Blade removal when 76 percent of the silks were brown gave corn of the lightest test weight." Dungan (17) found in some later investigations that blade injury reduced the yield approximately in proportion to the percentage of leaf area removed. He concluded that the efficiency of the remaining leaves was slightly increased as a result of partial defoliation, since removing one-half of the leaves reduced the yield only 37 percent and removing two-thirds of the leaves reduced the yield but 49 percent, while removing all the leaves resulted

in a reduction of 100 percent. The results were obtained when the treatment was given between "tasseling" and "fresh silk" stages.

Dungan (16) studied also the effect of different kinds of leaf mutilation on the yield of corn. He found, in every type of leaf injury, that the greatest reduction in yield occurred at the early silk stage, reduction in yield becoming progressively less as the plant approached maturity. He removed one-half the leaf area in the following ways with the accompanying reduction in yield: Tip one-half of each blade, 43 percent; alternate sections of sides of blades, 42 percent; one side of each blade, 30 percent; one-half of all the blades, 22 percent. Breaking the midribs reduced the yield 11 percent and cutting across the leaf to the midrib on each side 4 percent. The foregoing results are all for the period when three-fourths of the silks were brown. An earlier period would probably have given greater decreases in yield. Breaking the midrib and cutting across the leaf about 3 inches from the plant when the corn was "10 percent in silk" reduced yields 23 and 20 percent, respectively.

Hume and Franzke (29) studied the effect of: (a) Total leaf removal; (b) splitting the leaves along each side of the midrib; and (c) splitting the leaves and breaking the midribs. They obtained only slight reduction in yield from the two latter types of damage, the most severe injury occurring in the interval between tasseling and the milk stage. Removal of all leaves caused a reduction in yield of 44 percent when the corn was knee high, 89 percent when in the late pollinating stage, and 40 percent when in the milk stage. They agree with Dungan that the most critical period for leaf removal is between the time when the tassels have fully emerged and the time when the silks have turned brown, or between the "full tassel" and "blister" stages.

Loomis and Burnett (36) removed various portions of leaves of corn at several stages of maturity and concluded that "any leaf removal tends to reduce yields but reduction is greatest at early silk stage."

The importance of a maximum photosynthetic area is clearly shown by the references cited above. Several other workers have indirectly obtained similar results in entirely different types of investigation. Many farmers believe that suckers or tillers are detrimental to corn. The word "sucker" probably originated from the idea that tillers on corn rob the main plant. Many workers have performed "suckering" experiments, yet none of the results have shown any advantage from sucker removal. Montgomery (40) found that removing suckers, at

all rates of planting from one to six kernels per hill, reduced the yield. With three kernels planted per hill the reduction was 5.2 bushels per acre. This was under Nebraska conditions where a maximum leaf area would not seem to be as important as in more humid regions. DeBaun (10), Hepler (27) and Ricks (52) all report no increases in yield from sucker removal. Thompson (57) and Thompson, Mills and Wessels (58) conclude that removing the suckers of sweet corn is an unnecessary and even harmful operation. They state that late sucker removal was especially injurious. The Arkansas Experiment Station (2 and 3) found that removal of suckers of field corn reduced the yield where yields were over 45 bushels per acre but gave no decrease on soil which yielded 35 bushels per acre. This was perhaps because the limiting factor was soil fertility rather than carbohydrate elaboration. Dungan (19) defoliated the main plant and left leaves on the suckers and obtained a striking increase in yield over defoliated plants which had no suckers.

Sayre, Morris and Richey (54), in a study of accumulations of carbohydrates in corn stems, found that leaf removal caused a decrease in carbohydrate accumulation with a consequent reduction in yield. Culpepper and Magoon (8) working with sweet corn, removed both leaves and roots in varying percentages and at several stages of maturity. They reported that both leaf removal and root pruning reduced yields greatly, especially at silking time. Defoliation was more injurious than root pruning.

The effect on yield of injury to parts of the corn plant other than the leaves, is an important consideration in the adjustment of hail losses. Many farmers have attached more importance to slight bruises on the stalk than to severe leaf injury. Dungan (12 and 13) mentioned injury to stalks and ears in some of his earlier studies but did not separate it from leaf injury. Considerable work has been done on the effect of removing tassels. Leonard and Kiesselbach (35), in an 8-year test in which the tassels were pulled out at the top joint without injury to the leaves, obtained a yield of 43.6 bushels for the detasseled plants and 42.9 bushels for the normal plants. Alternate normal and detasseled rows were used, so plenty of pollen was available. Gardner (24), Newman (42), Smith (56), Watson (60), and Kimbrough (34) all found that the yield of corn was increased by removing the tassels. Morrow (41) reported no differences and Hayward (26), Ingersoll (31), and Mills (39) obtained reduced yields from detasseling. Ingersoll showed severe reduction in yields, but presented only 1 year's results.

Dibble and Marston (11) in corn borer control studies, removed varying portions of the stalk above the ear after the

silks had turned brown. Removing only the tassels reduced yields 5.4 percent, while cutting midway between ear and tassel caused a 12.9 percent reduction and cutting just above the ear reduced the yield 29.5 percent. The latter injury would reduce the effective leaf area by 50 percent or more. Reduction in yield due to poor pollination is seldom an important factor in hail damage. Work in crossing corn has shown that one-third or even one-fourth of the normal number of tassels is sufficient to give good pollination. A storm which destroyed two-thirds of the tassels would so injure the plants otherwise that poor pollination probably would not be a significant factor.

PURPOSE OF THE INVESTIGATION

In 1928 when these investigations were begun, little experimental work had been done to determine the effect of mechanical injury on the yield of crops. The relative importance of leaf damage and stalk damage, the extent of recovery of crops damaged at different stages of growth, the stage of development of the crop when injury would result in least recovery or greatest reduction in yield, the relation between reduction in leaf area and yield, and the effect of bruises on infection by smut organisms, all were questions arising in insurance adjustment of hail losses concerning which there were few experimental data available.

Two problems were studied: (1) Effect of injury in imitation of hail damage on the yield of corn, reported in this bulletin; and (2) effect of mechanical injury on the efficiency of corn leaves (see footnote p. 5).

Two main types of injury are recognized in natural hail damage to corn. The first of these is leaf injury, which may vary from that caused by scattered hailstones, which merely tear a few holes in the leaves or break an occasional midrib, to severe injury, where all the leaves are torn into small shreds and a large portion of the leaf area is entirely removed from the plant. The other type is stalk and ear damage. Stalk injuries vary from small bruises which scarcely discolor the cuticle beneath the leaf sheath, to severe lesions caused by large hail driven by a high wind. If the injury is from large hail driven by a high wind the stalks suffer deep bruises which penetrate well into the pith, and the stalks may even be broken off by the force of the blow. Hail at silking time may bruise the silks, resulting in poor pollination. Later in the season the kernels may be crushed by hail stones resulting in a bruised or moldy spot on the ear.

This investigation was started in 1928 on a limited scale and was gradually increased in scope until in 1931 and 1932 the

test fields were about 7 acres in area and involved many degrees and types of injury. The following problems have been considered:

I. Effect of leaf injury on yield.
   A. Relation between percentage of leaves removed and reduc- in yield.
   B. Relation between the stage of maturity, when the leaves are removed, and yield.
   C. The effect of different types of leaf injury on yield.
   D. Response of different varieties of corn to leaf injury.
   E. Effect of leaf removal early in the season on time of maturity.

II. Effect of stalk and ear injury on yield.
   A. Relation between stage of maturity when stalks and ears are bruised and yield.
   B. Relation between stalk bruises, broken stalks and yield.
   C. Comparative importance of leaf injury and stalk and ear injury in decreasing yields.
   D. Effect of ear bruises on the market grade of corn.

III. Effect of leaf, stalk and ear injury on amount of infection by corn smut.

IV. Influence of dry weather on effect of injury.

Investigations by other workers who have studied the effect of leaf injury and leaf removal on the yield of corn all indicate rather strongly that retention of the normal leaf area of the corn plant is conducive to maximum yields under favorable soil and climatic conditions. Whether unfavorable conditions will accentuate or minimize the effect of leaf injury is a question which perhaps has not been so definitely settled, yet is one with which the hail insurance adjuster is frequently confronted. It is important also in determining whether simulated hail injury will have the same effect as natural hail injury, even though it is very similar in appearance. The adjuster and the farmer are both inclined to contend that dry weather following a hail storm increases the damage from hail over that produced if normal weather ensues. The adjusters claim also that artificial damage shows a greater decrease in yield than would result from the same damage caused by hail, as there is always rain and cool weather during and after a hail storm, whereas the artificial hail treatment usually is given during clear weather. An effort will be made in discussing the data obtained from these investigations partially to answer some of these questions.

EXPERIMENTAL

MATERIALS AND METHODS

The following outline shows the general plan of the investigation:

	Type of injury	*Year*	*No. of replications*	*Dates of injury*
A.	Stripping. All leaf blades removed	'28	1 (3 rows)	10 to 12 day intervals 6/9 to 9/10
		29	3	Weekly—June 1 to Sept. 9
		30	6	" " 3 " " 8
		31	8	" " 2 " " 7
		32	8	" " 6 " " 5
B.	Shredding. All leaves severely shredded, about 50% of total leaf area removed	Same as A.		Same as A.
C.	Bruising. Each stalk struck five blows and each ear struck 2 blows	'29	3	Weekly—July 15 to Sept. 9
		30	6	" " 10 " " 8
		31	8	" " 8 " " 7
		32	8	" " 6 " " 5
D.	Bruising and shredding. A combination of B and C	'28	1 (3 rows)	10 to 12 day intervals
		30	6	Weekly—July 10 to Sept. 8
		31	8	" " 8 " " 7
		32	8	" " 6 " " 5
E.	Removal of one-third of leaves.	'30	6	Weekly—June 3 to Sept. 8
		31	8	" " 2 " " 7
		32	8	" " 6 " " 5
F.	Removal of two-thirds of the leaves	Same as E.		Same as E.
G.	Variety comparisons. Comparative effect of shredding on different varieties.	'30	3 (3 rows)	Two stages——full tassel stage and milk stage.
		31	3 (3 rows)	
		32	3 (3 rows)	
H.	Five types of leaf injury. 1. Half of each leaf removed. 2. Half of each leaf shredded. 3. Leaves cut to midrib opposite. 4. Leaves cut to midrib alternate. 5. Midrib cut.	'30	6	Three stages—just before the tassels emerged; full tassel stage; milk stage.
		31	6	
		32	6	

A description of the different types of injury, the methods employed and the general plan of the investigation follow.

Stripping, or total leaf removal, was accomplished early in the

season before the growing point had reached the surface, by cutting the plants off at the surface of the ground, and after the growing point had reached the surface by cutting the plants off above the growing point and stripping off the lower leaves. As the tasseling stage was reached all unrolled leaves were stripped off leaving only the top leaves rolled about the tassel. Later, after all leaves had unrolled and the tassel was fully out, all the leaves were stripped off. Stripping was accomplished by striking downward with a flat stick with a sharp edge, along the sides of the plants. This usually tore the entire leaf blades from the sheaths at their junction. When a shred of leaf blade remained on the sheath it was removed by hand. This type of injury will be referred to hereafter as "stripping." In the early stages of growth it means removal of all unrolled leaves as well as all leaf sheaths above the ground or above the growing point. Later in the season, after the growing point had reached a height of 25 to 30 inches and two to three nodes were visible, it means removal of all unrolled

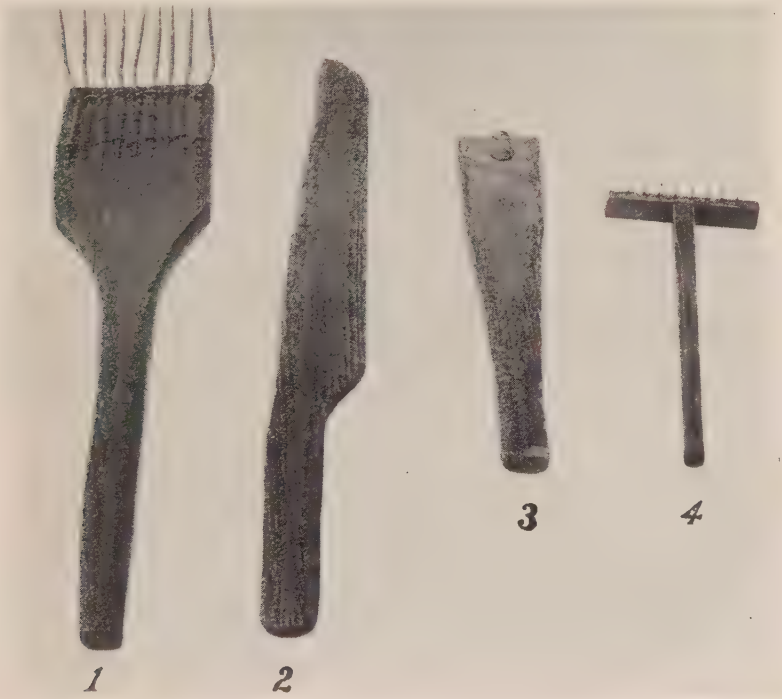

Fig. 1. Instruments used in injuring the corn. (1) Used in shredding the leaves. (2) Used in stripping off the leaves. (3) Used in bruising stalks and ears. (4) Used in splitting the leaves without removing any leaf material.

leaf blades but not the sheaths. Figures 2 to 5 inclusive, show this type of injury.

The shredding was done with a hook shredder made by fastening heavy wires, bent into hooks and sharpened, onto a paddle-like handle. (Fig. 1.) Several other devices were tried, but this shredder proved most satisfactory. By using a quick upward stroke the leaves could be shredded so that they looked almost exactly as if they had been damaged by hail. A downward stroke frequently tore the whole leaf from the stalk and was not satisfactory. The severity of the shredding could be governed by the number of strokes per hill and the force with which they were applied. A severe shredding tore each leaf

Fig. 2. Photo showing total leaf removal early in the season. From (left to right) row (1) border; (2) check; (3) cut off at the surface on June 3; (4) cut off at the surface on June 10; (5) normal plants to be cut off on June 17. (Compare with fig. 3 and 4.) (Photo June 10, 1930.)

into ribbons or shreds, ½-inch or less in width and removed 40 to 50 percent of the total leaf area. A few downward strokes with the back of the shredder broke the midribs which remained in a normal position and left the plants looking as if they had been damaged by a real hail storm. Figures 6, 7 and 8 show plants shredded according to the method described above. Figure 9 shows young corn plants (see legend) and fig. 10 shows typical plants injured by a hail storm.

Fig. 3. Photo showing recovery following total leaf removal in June. From right to left, (1) border, (2) check, (3) cut off at the surface on June 3, (4) cut off at the surface on June 10. These are same rows as in fig. 2, but taken from the other direction. (Photo Aug. 25, 1930.)

Fig. 4. Photo showing total leaf removal at weekly intervals early in the season and also subsequent recovery. Treatment was as follows from right to left: Row (1) (extreme right) border; (2) check; (3) cut off at the surface of the ground on June 3; (4) cut off at the surface of the ground on June 10; (5) cut off at the surface of the ground on June 17; (6) cut to a height of 4 inches on June 24; (7) cut to a height of 1 foot on July 1; (8) normal corn on July 1 to be cut off at a height of 30 inches on July 8. (Compare with figs. 2 and 3.) (Photo July 1, 1930.)

Fig. 5. Photo showing plants which had been defoliated in late July and early August. From right to left rows stripped on July 21, July 28, Aug. 4, and Aug. 11. (Photo Aug. 25, 1930.)

Fig. 6. Photo showing rows shredded early in the season. (Left to right) Row (1) Shredded on June 17; (2) Shredded on June 24; (3) Normal plants to be shredded on July 1. (Photo June 24, 1930.)

Fig. 7. Photo showing rows shredded in July. (Left to right) Row (1) Shredded on July 1; (2) Shredded on July 8; (3) Normal plants to be shredded on July 15. (Photo July 9, 1930.)

Fig. 8. Photo showing rows shredded in late July and August. (Left to right) (1) Shredded July 28; (2) Shredded Aug. 4; (3) Shredded Aug. 11; (4) Shredded Aug. 18. (Photo Aug. 25, 1930.)

Fig. 9. Photo of young corn plants showing total defoliation and shredding and recovery. (1) Normal Plant pulled on June 3; (2) Normal plant pulled on June 10; (3) Cut off at the surface on June 3 and pulled on June 10; (4) Shredded on June 3 and pulled on June 10; (5) Shredded on June 10; (6) Cut off at the surface on June 10. (Photo June 11, 1930.) (The plant pulled on June 3 was kept in a tight can until photo was taken.)

Bruising of stalks and ears. The stalks and ears were bruised by striking each stalk five blows and each ear two blows with an instrument which consisted of a paddle-like handle about 20 inches long on which was fastened a hardwood knob about ½-inch in diameter. (Fig. 1.) The blows which were distributed uniformly over the lower two-thirds of the plant, were struck hard enough so that at least one or two of them caused the knob to sink into the stalk, producing a bruise similar to that from a medium sized hail stone striking the stalk with great force. The two blows on the ear were struck with sufficient force to penetrate the husks and bruise the kernels. Typical bruised stalks and ears are shown in figs. 11 and 12.

One-third and two-thirds defoliation. One-third of the leaves were removed from one series of plots and two-thirds from another series. The leaves were removed by jerking the leaf blade from the plant leaving the sheath intact.

Variety response to leaf injury. During the progress of these investigations the question of variety resistance to injury was

raised. If certain varieties, because of some morphological or physiological characteristic, might be better able to withstand or overcome the effect of hail injury, they would have a distinct advantage in a region where hail is common. In the hope of answering this question a variety comparison was inaugurated in 1930. For this experiment six varieties or strains were used, as follows:

1. Golden King, a vigorous, early yellow dent variety which

Fig. 10. Corn plants from a field near Zearing, Iowa, injured by a hail storm on July 6. Plants brought in and photographed on July 14. The field yielded 30 bushels per acre.

has proved to be a good yielder, adapted to the northern part of Iowa.

2. Osterland Yellow Dent, a strain of Reid Yellow Dent developed by H. F. Osterland of Franklin County, Iowa. It is adapted to the north central part of Iowa and yields fairly well.

3. Krug, a productive yellow dent variety, rather late maturing, is adapted to the south central and southern part of Iowa.

4. Hybrids 972, 973, and 976 all of which were developed by the Iowa Agricultural Experiment Station as part of its corn breeding project. These are rather late-maturing, vigorous, high yielding, single cross hybrids. A comparison of the varieties with respect to earliness shows that the average date when they were fully tasseled was as follows: Golden King, July 17; Osterland, July 22; Krug, July 28; No. 972, July 30; No. 973 and 976, Aug. 1.

The injury consisted of severe shredding of all leaves at two different stages of maturity, the full tassel stage and the milk stage. These stages were used because they were rather definite, especially the full tassel stage. It was necessary, in order to get a fair comparison, to inflict the injury on each variety at the same stage of development.

In order to reduce the error due to soil heterogenity, all the

Fig. 11. Stalks bruised in July. The three at the right are split to show how far the injury extended. The three at the left show the outward appearance of typical bruises. (Photo Oct. 18, 1932.)

Fig. 12. Ears bruised on succeeding weekly intervals from silking stage (No. 1) to mature stage, (No. 10). Note the absence of mold on Nos. 1, 2, 3, 9 and 10 and the extent of the moldy spots on the others. (Photo Oct. 18, 1932.)

varieties were planted side by side in regular order, and to minimize border effect of one variety upon another they were planted in three-row plots, with a border row between each replication. Three replications for each date of injury were used, with check[3] plots on each side of each replication.

Minor leaf injury. In 1930 a study was begun to determine the effect of five types of leaf injury relatively less severe than those previously described, and also to determine whether an upset to translocation, such as would result from a hailstone tearing a hole in a leaf, or breaking the midrib, would seriously affect the yield. This phase of the problem consisted of five different types of leaf injury as follows:

1. The tip half of each leaf was cut off. This will be referred to as "half leaf."
2. The tip half of each leaf was shredded into ribbons about ¼ inch wide. It was impossible to do this without removing a small amount of leaf material but this never exceeded 1 or 2 percent. This will be referred to as "half shredded." (Fig. 14.)
3. Each leaf was cut from the outer edges to the midrib, about midway of the leaf, the cuts on each side being opposite each other. In other words, the leaf was cut in two except for the midrib. This will be referred to as "cut opposite."
4. Each leaf was cut from the outer edge to the midrib, the cut on one side being made about one-third of the distance from the tip to the base of the leaf and on the other side about two-thirds of the distance from the tip. While the leaf was cut entirely across, except for the midrib, the cuts were 8 to 10 inches apart instead of opposite. This will be referred to as "cut alternate."
5. The midrib was cut in two about midway of the leaf without injuring the blade. This will be referred to as "cut midrib."

[3] Throughout this publication "checks" or "check plots" means normal uninjured corn with which the yields of the injured plots are compared.

The studies just enumerated were carried on during 1930, 1931 and 1932. The five types of injury were inflicted at three stages of maturity as follows: (1) Pre-tassel stage, about a week before the tassels began to appear, when all but the top three or four leaves had unrolled; (2) full tassel stage, when the corn was practically all tasseled and about 50 percent silked; and (3) early milk stage, when most of the ears were "in the milk" and before any had developed to the soft dough stage.

These three stages were selected as being the most critical in the development of the plant, so that any differences in the effect of each type of injury would be more certain to be discovered. Six replications were used and the work was carefully done so that the experimental error would be kept at a minimum.

LAYOUT OF PLOTS

In order to minimize border effect and still avoid an excessive number of guard rows, the layout of the plots was as follows. The field was divided into ranges 14 hills wide, the two end hills being used as border and each range being used for one type of injury, as stripping, shredding, etc. Within a replication the check rows were protected by guard rows and the injured rows, damaged at weekly intervals, were treated in regular order so that each row had a row which had been injured the previous week on one side and a row injured the succeeding week on the other side. Each replication consisted of from 10 to 15 rows with check rows on each side. ("Eight replications" means eight complete treatments, not nine.)

The corn used each year was an open-pollinated strain of Reid Yellow Dent, except in 1929 when a hybrid consisting of a double cross was used. Rows were 42 inches apart each way and, except in 1932, the corn was planted thickly and thinned to insure a uniform stand.

In order to measure the percentage of leaf area removed, the weight of leaves removed in each type of injury was obtained. By comparing these weights with the total weight of leaves from the stripped plots it was possible to calculate rather accurately the percentage of leaf area removed in each type of injury. Table 1 shows the percentage of leaf area removed, based on the total weight of leaves removed from the stripped plots. Weights were not taken in 1928 nor in 1932. In 1928 the shredding was not as severe as in the following years but in 1932 it was very similar to that of the 3 previous years.

In the case of one-third defoliation the method of leaf removal followed was to remove the lowest leaf, leave the next two, remove the fourth, leave the next two, remove the seventh,

leave the next two, and so on to the top of the plant. The same plan was followed with two-thirds defoliation.

THE GROWTH AND DEVELOPMENT OF THE CORN PLANT

It is recognized by hail insurance adjusters that the stage of development at which a corn plant is injured is very important in determining how seriously the injury will affect the yield. Corn, like other members of the Gramineae, develops by successively unrolling the leaves from within. The number of leaves which a plant will eventually have is determined early in its development, and after this number is fixed nothing in the plant's environment can change it. Thus, an injury which destroyed the first three leaves which had unrolled while the growing point or meristem was still beneath the soil surface would permanently deprive the plant of that portion of its potential photosynthetic area. On the other hand, the remaining leaves would unroll normally as the growing point pushed upward so that at maturity such a plant would appear normal except for the lack of the three small lower leaves.

In order that the results of this investigation might be most useful in hail loss adjustments, careful notes were kept on the progressive development of the corn plant. Observations were recorded each week during the growth period for the 5 years that the experiment was in progress. Notes were taken on

TABLE 1. PERCENTAGE OF LEAF AREA REMOVED FROM "SHREDDED," "ONE-THIRD DEFOLIATED," AND "TWO-THIRDS DEFOLIATED" PLOTS.

Mean stage of maturity	Mean date	Percentage of leaf area removed					
		All leaves shredded*		One-third defoliated		Two-thirds defoliated	
		1929	1931	1930	1931	1930	1931
5 inches high, 4 leaves	6– 1	36			21		50
7 inches high, 5 leaves	6– 8	63	47	25	25	54	59
14 inches high, 7 leaves	6–15	84	46	25	29	45	49
2 feet high, 9 leaves	6–22	63	55	22	30	43	53
3 feet high, 11 leaves	6–29	42	71	33	38	61	69
4½ feet high, 13 leaves	7– 6	43	47	29	29	56	57
6 feet high, first tassels	7–13	39	53	33	31	63	59
8 feet high, 40 percent tasseled	7–20	32	48	33	34	61	72
85 percent tasseled, 60 percent silked	7–27	30	45	31	35	60	74
75 percent of silks dead	8– 3	41	49	38	37	72	68
Blister to early milk stage	8–10	33	52	33	37	66	73
Milk stage	8–17	20	53	40	36	76	71
Soft dough stage	8–24	19	54	39	37	69	71
Hard dough stage	8–31			41		76	
Nearly mature	9– 7	39					
Mean percentage		42	51.5	32.5	32.2	61.5	63.5

*No crop from shredded plots in 1930 because of drouth.

TABLE 2. WEIGHT OF LEAVES UNROLLED AT SUCCESSIVE STAGES OF MATURITY AND PERCENTAGE OF MATURE WEIGHT. 1929-1930-1931. (COMPUTED ON A 12-HILL BASIS.)

Mean stage of maturity	Mean date	1929		1930		1931		Mean wt.	Mean percent of 7/27 wt.	Mean height of growing point
		Wt. of leaves in lbs.	Percent of wt. on 8/3	Wt. of leaves in lbs.	Percent of wt. on 7/27	Wt. of leaves in lbs.	Percent of wt. on 7/20			
5 inches high, 4 leaves	6– 1	0.093	0.5			0.1	0.6	0.096	0.54	Below
7 inches high, 5 leaves	6– 8	0.56	2.9	0.24	1.5	0.5	2.8	0.13	0.73	the
14 inches high, 7 leaves	6–15	1.03	5.4	0.89	5.4	1.8	10.1	1.25	7.03	Surface
2 feet high, 9 leaves	6–22	3.20	16.7	2.80	17.1	5.8	32.4	3.59	20.20	2″
3 feet high, 11 leaves	6–29	6.60	34.4	5.70	34.8	11.8	65.9	8.03	45.10	11″
4½ feet high, 13 leaves	7– 6	10.90	56.8	11.10	67.7	17.4	97.2	13.10	73.70	30″
6 feet high, first tassels	7–13	14.60	76.0	13.70	83.5	18.1	101.1	15.50	86.90	
8 feet high, 40 percent tasseled	7–20	17.50	91.1	16.20	98.9	17.9	100.0	17.30	97.30	
85 percent tasseled, 60 percent silked	7–27	19.30	100.5	16.40	100.0	17.7		17.80	100.00	
75 percent silks dead	8– 3	19.20	100.0	13.40		16.6		16.40		
Blister to early milk stage	8–10	20.00		12.10		15.1		15.80		
Milk stage	8–17	22.50		10.10		13.7		15.50		
Soft dough	8–24	20.50		10.50		10.2		13.70		
Hard dough	8–31			8.50						
Nearly mature	9– 7	15.50								

height of plant, number of leaves unrolled, and height of the growing point previous to the tasseling stage. In the latter part of the season the stage of maturity was indicated by the percentage of tassels shedding pollen, percentage of plants which had produced silks, percentage of silks which had died (indicating completion of fertilization) and stages in the development of the kernel up to maturity.

In order to get a still more accurate picture of the weekly development of the plants, the weights of leaves obtained from the stripped plants were used to determine the percentage of leaves unrolled at each period.

The data which are presented in table 2[4] show that for the first 2 or 3 weeks in the development of the plant, a very small percentage of the total leaf area has unrolled. After this time vegetative development progresses at a very rapid rate up to the tasseling period. This fact has a very important bearing on the results of this investigation as well as on the results of actual hail injury at different stages in the development of the corn plant.

EFFECT OF LEAF INJURY ON THE YIELD AND QUALITY OF CORN

Discussion of results of these investigations is arranged by topics rather than by years. The severe drouth of 1930, however, caused such a variation in results from those of the other years that they are not included in the averages but will be discussed separately.

The work with corn naturally divides itself into two main phases, leaf injury and stalk injury. As mentioned earlier the comparative effect on yield of these two types of injury is the subject of considerable difference of opinion, especially among hail insurance adjusters and farmers. Perhaps a lack of knowledge of the function of the leaves and stalks is the most important reason for this.

In most cases the work was done at weekly intervals, but it should be recognized that corn is not at the same stage of maturity on a certain date every season. It is important to remember also that the effect of a certain type of injury is very different at different stages of maturity. In order to be certain that this factor did not cause confusion in drawing conclusions from the results of different seasons, the notes on maturity described previously were taken each time the corn was treated.

[4] It should be noted here that in many of the tables results were computed to two places but that to save space only one place was tabulated. This frequently makes a slight difference in the result given in the table, especially where several columns of figures are involved in a mean result.

In tabulating the results the stage of maturity on the date the injury was inflicted is included in each table. The graphs are arranged so that the points indicating yield are placed on the graph by stage of maturity rather than by date. The dates given on the graphs are average dates for the period covered, and the stage of maturity is also average for the years indicated. Presenting the data by stage of maturity, rather than by date, minimizes differences due to varying stages of maturity in different seasons. It should be emphasized here that the dates on the graphs are merely for reference.[5]

A very complete record was kept of yield and quality of corn from each type of injury. Each row of each replication was harvested and weighed separately. Notes were taken on number of good ears, number of nubbins and number of moldy ears. Stand counts were made each year so the effect of stand on yield could be taken into consideration in the final results. A representative 25-pound sample from each type of injury at each date was saved and dried for use in moisture and shelling percentage determinations. Bushel test weights were taken on the shelled samples. Final yields were computed in bushels of air dry (13 percent moisture) shelled corn per acre. All yields of injured rows were also computed as a percentage of the check.

A statistical analysis of the data presented in this paper was made by the method introduced by Fisher (20) and called by him "Analysis of variance." Because of lack of space the detailed description and computation are omitted. Whenever results are mentioned as being "significant" or "not significant" it can be taken for granted that the data were analyzed by this method.

EFFECT OF COMPLETE DEFOLIATION (STRIPPING)

Total defoliation or stripping had one distinct advantage over other types of leaf injury when viewed from the experimental viewpoint in that it was a definite type of injury which could be repeated exactly each time and each season. It was possible

[5] The points on the graphs showing mean yields were located by the following method. Points showing yields for each weekly period for each season were located on the graph according to yield and stage of maturity at the date for that season. The points for each season were then connected by straight lines. A series of points across the graph were then located equal distances apart. The mean yield for each of these points was then computed by using the values of each season as obtained from the lines connecting the annual yields. This method was followed in order that the yield obtained at the same stage of maturity would be used rather than the yield at the same date. The mean yields in the tables were computed by averaging the yields obtained at the dates nearest the mean date. In other words, the percentage yields in the tables are actual mean yields at given dates, while the mean yields in the graphs are based on probable yields at comparable stages of maturity. For this reason the mean yields in the tables do not always check with the points showing mean yield on the graphs.

TABLE 3. YIELD OF CORN FROM PLANTS TOTALLY DEFOLIATED AT VARIOUS STAGES OF DEVELOPMENT.

Mean stage of maturity	Mean date	Yield in bushels per acre				Mean yield	
		1928	1929	1931	1932	Bu. per acre	Percentage of check
Check		49.0	85.1	52.0	67.6	63.4	
5 inches high, 4 leaves	6– 1		80.1	44.7		62.4	91.3
7 inches high, 5 leaves	6– 8	35.1	87.9	44.5	64.1	57.9	91.3
14 inches high, 7 leaves	6–15		78.4	44.5	39.7	52.5	77.0
2 feet high, 9 leaves	6–22	30.3	64.3	38.9	37.3	42.7	67.4
3 feet high, 11 leaves	6–29	31.2	50.9	15.3	35.0	33.1	52.2
4½ feet high, 13 leaves	7– 6		28.2	9.8	20.2	14.6	21.4
6 feet high, first tassels	7–13	8.6	17.2	3.9	1.3	7.8	12.3
8 feet high, 40 percent tasseled	7–20	0.1	0.3	0.5	0.0	0.2	0.3
85 percent tasseled, 60 percent silked	7–27	0.0	1.0	3.4	3.4	2.0	3.0
75 percent of silks dead	8– 3	9.3	12.3	10.8	14.6	11.7	18.5
Blister to early milk stage	8–10		19.9	19.4	26.5	21.9	32.1
Milk stage	8–17	23.9	39.0	27.7	39.8	32.6	51.4
Soft dough stage	8–24		55.0	37.0	48.2	46.7	68.5
Hard dough stage	8–31	38.0	68.7	44.6	58.0	52.3	82.5
Nearly mature	9– 7		86.6	45.0	62.3	64.5	94.6

to repeat the experiment during succeeding seasons and feel certain that any differences in results were due to environment and not to differences in the severity of the injury. A comparison of the results of stripping with other types of leaf injury bears out this assertion.

Table 3 and fig. 13 show the effect on yield of total defoliation at weekly intervals in 1928, 1929, 1931 and 1932. Figures 2, 3, 4 and 5 show the appearance of the plots stripped at various stages of development. A study of these data indicates the importance of a maximum photosynthetic area. In early June, when the plant has only five or six small leaves, cutting the plant off at the surface caused only a 5 to 10 percent reduction in yield since the remainder of the leaves unrolled normally, and at tasseling time the injured rows appeared almost normal. But as the season progressed and a greater and greater proportion of the total leaf area had developed and was consequently removed, the yield dropped sharply, in almost direct ratio to the percentage of leaf area removed. In mid July when the leaves were all unrolled and the photosynthetic area was completely removed by defoliation the yield approached zero. This condition was reached before the stage of total leaf removal because removal of 90 to 95 percent of the leaves just as the corn was beginning to show a few tassels delayed the development of silks but did not delay shedding of pollen. As a result even though the plants had a small amount of leaf area

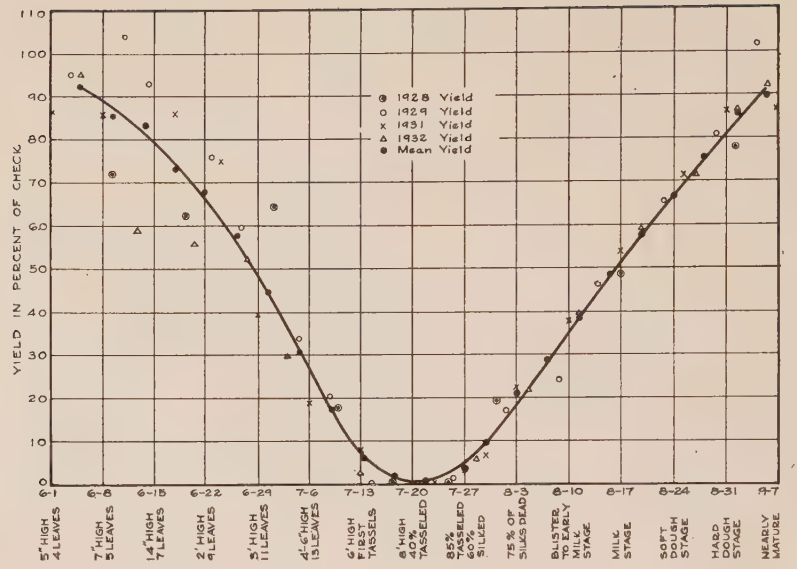

Fig. 13. Yield of corn in percentage of check from plants totally defoliated at various stages of maturity.

left at the top they yielded very little because of poor pollination.

As fig. 13 shows, the period during which total leaf removal resulted in almost total loss of yield extended from the first tassel stage to the stage when the corn was 50 to 75 percent pollinated, a period of about 2 weeks, after which the yield began to rise sharply. Of course this does not mean that during the last week in July when pollination was being completed that 10 to 15 percent of the crop was "made." There was undoubtedly reserve material accumulating in the stalk and leaf sheaths which was used to produce a portion of a crop, even though at the time of defoliation little if any carbohydrate material had been deposited in the kernels. As the season advanced and the ears continued to develop, leaf removal caused progressively less decrease in yield. This was not because the leaves ceased to be important but because more and more of the crop had been "made" before the leaves were removed.

Reference to table 2 shows how closely the reduction in yield followed the reduction in leaf area of the stripped plants from four leaves until first tassels. The values in this table were obtained by using the weight of leaf removed on the date when all leaves were unrolled as 100 percent and computing the percentage removed on preceding weeks from this figure. The data in table 2 shows that in 1929 and 1931 the weight of leaves

had reached a maximum before all of the leaves had unrolled. Consequently the figures given for the period just preceding the 100 percent stage are estimates. In 1929 the weight of leaves removed continued to increase until Aug. 19, although all leaves were unrolled about Aug. 2. In 1930, because of a severe drouth, the maximum weight of leaves was reached on July 28, a day or two before all of the leaves were unrolled, and began to drop rather rapidly from then on, weighing only 50 percent as much on Sept. 1 as on July 28. In 1931 the maximum weight was reached on July 13, a week before all leaves were unrolled. The weight decreased rather slowly at first and then more rapidly until on Aug. 24 the leaves weighed only 56 percent as much as on July 13. This decrease in 1931 was due partly to drouth and firing of the lower leaves and partly to the fact that the corn matured very rapidly the latter part of August.

EFFECT ON WEIGHT PER BUSHEL

The effect on quality of the corn produced on the stripped plants, was similar to the results obtained by Dungan (14). Defoliation before the corn had unrolled 40 percent of its leaves (June 20) resulted in only a slight decrease in test weight per bushel (table 4), while from then to the tasseling period (July

TABLE 4. MEAN WEIGHT PER BUSHEL OF CORN SUBJECTED TO SEVERAL TYPES OF INJURY AT VARIOUS STAGES OF DEVELOPMENT. 1929-1931-1932

Mean stage of maturity	Mean date	Mean weight per bushel					
		Stripped	Shredded	One-third defoliated	Two-thirds defoliated	Stalks and ears bruised	Stalks and ears bruised and leaves shredded
Check		55.2	55.7	56.1	55.8	55.4	56.6
5 inches high, 4 leaves	6– 1	54.9	55.7	56.4	55.3		
7 inches high, 5 leaves	6– 8	55.3	55.6	56.5	55.1		
14 inches high, 7 leaves	6–15	54.9	55.2	56.4	55.2		
2 feet high, 9 leaves	6–22	54.6	55.5	55.9	55.5		
3 feet high, 11 leaves	6–29	52.3	55.1	54.8	55.6		
4½ feet high, 13 leaves	7– 6	53.1	53.5	55.5	54.6	55.8	55.3
6 feet high, first tassels	7–13	——*	54.9	55.9	55.2	55.4	53.7
8 feet high, 40 percent tasseled	7–20	——*	54.4	55.7	54.3	54.9	54.4
85 percent tasseled, 60 percent silked	7–27	46.2	54.6	54.8	54.2	55.1	54.5
75 percent of silks dead	8– 3	46.3	53.3	54.6	53.8	54.6	53.1
Blister to early milk stage	8–10	47.4	52.2	55.0	52.6	54.6	54.8
Milk stage	8–17	49.7	54.1	55.4	52.7	54.0	53.3
Soft dough stage	8–24	52.6	54.8	54.7	53.6	54.8	54.4
Hard dough stage	8–31	53.8	55.2	55.5	54.7	54.7	54.6
Nearly mature	9– 7	55.2	55.3	56.0	55.2	55.2	55.4

*Not enough corn from all replications to obtain weight per bushel.

13) the test weight was reduced from 3 to 5 percent. During the 3-week period from the time the corn was 60 percent silked (July 27) to the milk stage (Aug. 17) the test weight was decreased about 15 percent and during the period from Aug. 17 to Sept. 8, while the ears were changing from the milk stage to the hard dough stage, the test weight was 96.4 percent of check. Early in the season the size of the ears was adjusted to the photosynthetic area and the ears, though small, produced normally developed kernels, but defoliation later in the season, after the size of the ear had been determined under normal conditions, caused chaffy, poorly developed kernels low in weight per bushel. Toward the end of the growing season, after the ear was already fairly well developed, defoliation had less effect on the weight per bushel. During the critical period in the development of the crop, from the time when the first tassels were emerging until silking was about complete (July 13 to 27), there was not enough corn produced on the entire eight replications to take a test weight. It should be noted that when dates are mentioned they are merely to indicate the time of the injury. The stage of maturity is the important factor.

Weight per bushel was taken on the other types of injury also, during each year of the investigation. On the types of injury in which there was a severe reduction in leaf area, the trend in bushel test weight was similar to that obtained with stripping, although the variation was smaller. When the leaves removed amounted to less than one-half of the total leaf area, there was little or no reduction in weight per bushel. Evidently there must be a considerable reduction in leaf area before chaffy corn will result.

EFFECT OF SEVERE SHREDDING

Leaf shredding as carried out in this investigation, while having the advantage of more nearly simulating actual hail damage than any other leaf treatment, has two distinct disadvantages. First, it is difficult to be certain that the injury is equally severe from week to week and the personal element is a large factor in the treatment. In order to check the method and to have some idea of the percentage of leaves removed, the shreddings were collected and weighed and the leaf area removed was computed according to the plan described on page 22. This plan was followed in 1929, 1930 and 1931 and the data showing the percentage of leaves removed will be found in table 1.

The second disadvantage in this type of leaf injury is the difficulty of describing the treatment accurately. The method of shredding the leaves is described on page 14 and the appearance of shredded plants is shown in figs. 6, 7 and 8.

TABLE 5. YIELD OF CORN FROM PLANTS THE LEAVES OF WHICH WERE SHREDDED AT VARIOUS STAGES OF DEVELOPMENT.

Mean stage of maturity	Mean date	Yield in bushel per acre				Mean yield for 1929-1931-1932	
		1928	1929	1931	1932	Bu. per per acre	Percent of check
Check		49.0	78.3	63.0	54.6	65.3	
5 inches high, 4 leaves	6– 1		83.6	61.8		72.7	102.8
7 inches high, 5 leaves	6– 8	45.1	75.5	60.3	52.1	62.6	95.9
14 inches high, 7 leaves	6–15		84.9	61.3	55.3	67.2	102.9
2 feet high, 9 leaves	6–22	46.2	70.9	52.5	51.0	58.1	89.0
3 feet high, 11 leaves	6–29	43.7	71.3	35.8	39.6	48.9	74.9
4½ feet high, 13 leaves	7– 6		44.8	19.5	23.8	29.4	45.0
6 feet high, first tassels	7–13	38.3	31.4	16.1	24.2	23.9	36.6
8 feet high, 40 percent tasseled	7–20	39.0	45.3	27.1	25.1	32.5	49.8
85 percent tasseled, 60 percent silked	7–27	37.2	62.0	39.9	27.0	43.0	65.8
75 percent of silks dead	8– 3	39.3	54.5	42.4	32.0	43.0	65.8
Blister to early milk stage	8–10		66.7	42.3	31.7	46.9	71.8
Milk stage	8–17	44.9	66.1	50.5	35.3	50.6	77.5
Soft dough stage	8–24		70.1	50.6	42.6	54.4	83.3
Hard dough stage	8–31	47.7	71.3	56.0	48.1	58.5	89.6
Nearly mature	9– 7		76.7	60.4	50.2	62.4	95.6

Table 5 and figure 14 show the yields following leaf shredding for the years 1928, 1929, 1931 and 1932. A study of these data reveals the fact that leaf shredding gave much less uniform results from week to week and for the different seasons than were obtained from the leaf removal experiment. This greater lack of uniformity probably was due partly to differences in weather conditions but in large measure to differences in severity of shredding from week to week, and more especially from season to season. A comparison of figs. 14 and 13 should confirm this. It can be seen that where the injury was more definite, as in the case of total defoliation, the results for the different seasons are much more uniform. There is no doubt that the shredding was least severe in 1928. The difficulty of describing the method was recognized during that first season but rather than make a change it was determined, because of its close similarity to actual hail damage, to make the method more severe and to continue it. It could then be described as very thorough shredding of every leaf, with 30 to 50 percent of the leaf area removed.

Figure 14 and table 5 show that there was the greatest reduction in yield in 1931 of any of the 4 years included. This is believed to be due to more severe shredding in 1931 than in any of the other seasons. Table 1 shows a greater amount of leaf removed in 1931 than in 1929. The average removed in 1929 was 42 percent and in 1931 it was 51.5 percent. It will be noted that the percentage removed at weekly intervals is much more uniform

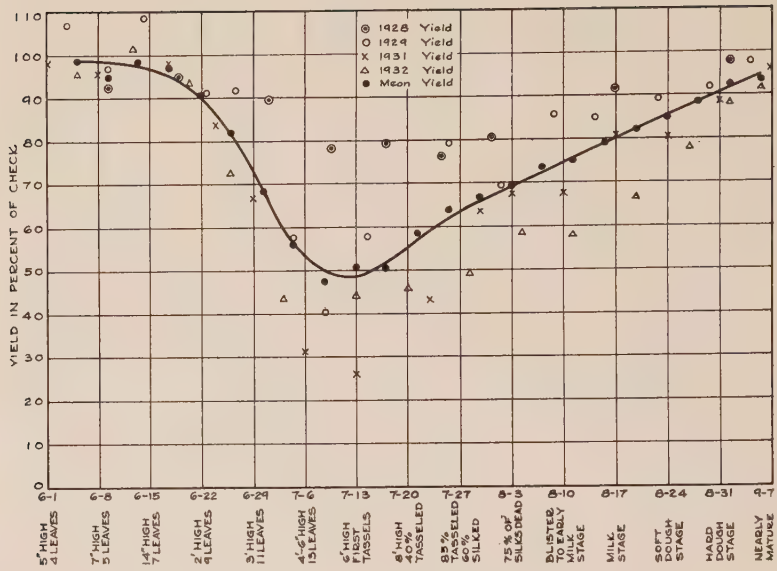

Fig. 14. Yield of corn in percentage of check from plants whose leaves were shredded at various stages of development.

from week to week in 1931 than in 1929, probably because removing a large percentage of the leaves made it easier to keep the shredding uniform throughout the season. Shredding in 1932 was about as severe as in 1931, although the yields averaged lower on the rows injured during the latter half of 1932. This decrease can be attributed to weather conditions. A severe dry spell during the tasseling and silking period caused four or five of the lower leaves to fire on that part of the plot not yet treated. Later, rains made it possible for the check rows to utilize all the leaf area which remained, which was perhaps 60 percent of normal. On the other hand, the shredded rows, which had already lost 40 percent of their leaves by firing, later lost 50 percent of their remaining leaves by shredding, leaving only about one-third of the normal leaf area. Since the effect of leaf removal seems to become progressively greater as the percentage removed approaches 100 (see one-third and two-thirds removal p. 34) it seems logical to attribute the lower yields of the plots shredded during the last half of 1932 to the condition described above.

A study of the data on shredding shows the same trends, with respect to effect on yield, as were obtained with total defoliation. Although the yearly results were more erratic, the means for the

4 years, as shown in fig. 14, approximate a fairly smooth curve. During the first half of June, when only five or six of the lower leaves had unrolled, severe shredding reduced the yield about 1 percent for the first treatment, 2 to 3 percent for the second and 4 to 5 percent for the third. Yields began to drop rather rapidly from then on, being about 85 percent, 65 percent and 48 percent of check for the next three treatments, respectively, the last of which was given just as the tassels were ready to emerge. Reference to table 1 shows that the time when yields began to drop rapidly coincides with the period when the leaves began to unroll more rapidly. This critical period continued for about 2 weeks during the tasseling and silking stage of the plant's development. If an average of 50 percent of the leaf area was removed by shredding, which is a reasonable assumption in the light of the data on percentage of leaf removed, it appears that the percentage of leaf removed at the most critical stage would reduce the yield proportionally. This result checks rather closely with the data on stripping. About June 29, when approximately 50 percent of the potential leaf area of the plant was removed in the stripped plots, the yield was about 50 percent of normal. (See data on one-third and two-thirds removal.)

After the critical tasseling and silking stage the yields again began to rise. There was a tendency (note also data on one-third and two-thirds defoliation, and bruising and shredding) for the yields to rise more rapidly at first than they did later in the period of ear development. This may be explained by assuming that during the period after the leaves were all unrolled and before ear development had got under way, there was a time when there was a maximum of photosynthesis without a corresponding storage reservoir in the ear. As a result carbohydrates had accumulated in the stalk and leaf sheaths to be later translocated to the rapidly developing ear. As soon as the ear was fully formed and this accumulated carbohydrate material had been translocated, the ear depended for its further development on the daily synthesis of carbohydrates and there resulted a slowing up in the rate of ear development to correspond to the daily rate of photosynthesis.

Another reason for the rapid development of the ears following pollination is the fact that young leaf tissue commonly is more vigorous and effective in synthesis and elaboration of nutrients, than older tissue. Because of the rapidity with which the leaves unroll just before and during the time the tassels are emerging, the silking plant has the largest proportion of young leaves. Many workers also assign a direct stimulating effect to the fertilization process.

EFFECT OF REMOVING ONE-THIRD AND TWO-THIRDS OF THE LEAVES

Experiments in which one-third and two-thirds of the leaves were removed were started in 1930 and continued in 1931 and 1932. Only the data for 1931 and 1932 will be included in this discussion. Leaves were removed at weekly intervals beginning early in June. The data on percentage of leaves removed in 1930 and 1931 show that there was a definite tendency early in the season to remove less than one-third and two-thirds, respectively, whereas at the end of the season there was a tendency to remove more than the intended percentage. This trend was discoverd at the end of the 1930 season, and an effort made to correct it in 1931 but with only partial success. It is reasonable to believe that the same tendency existed in 1932. The method of defoliation (described on page 22) should have given more accurate results. No satisfactory explanation of the difficulty has been discovered.

Table 6 and fig. 15 show that the trend in yields is very similar to that of the stripping and shredding experiments. There was a very slight decrease in yield for both the one-third and the two-thirds defoliation in the first 3 weeks, then there was a sharp

TABLE 6. YIELD OF CORN FROM PLANTS PARTIALLY DEFOLIATED AT DIFFERENT STAGES OF DEVELOPMENT.

Mean stage of maturity	Mean date	One-third of leaves removed				Two-thirds of leaves removed			
		Yield in bu. per A.		Mean yield		Yield in bu. per A.		Mean yield	
		1931	1932	Bu. per A.	Percent check	1931	1932	Bu. per A.	Percent check
Check		52.2	60.4	56.3		52.3	48.8	50.6	
5 inches high, 4 leaves	6– 1	54.3			104.0*	51.7		51.7	98.9*
7 inches high, 5 leaves	6– 8	50.2	62.4	56.3	100.0	48.8	50.6	49.7	98.2
14 inches high, 7 leaves	6–15	51.6	60.3	56.0	99.5	51.0	50.3	50.7	100.2
2 feet high, 9 leaves	6–22	52.2	59.3	55.8	99.1	48.8	46.9	47.9	94.7
3 feet high, 11 leaves	6–29	38.3	55.6	47.0	83.5	34.2	35.2	34.7	68.6
4½ feet high, 13 leaves	7–6	42.3	52.6	47.5	84.4	31.4	27.9	29.7	58.7
6 feet high, first tassels	7–13	40.8	43.6	42.2	75.0	24.4	17.1	20.8	41.1
8 feet high, 40 percent tasseled	7–20	34.8	44.1	39.5	70.2	16.8	10.6	13.7	27.1
85 percent tasseled, 60 percent silked	7–27	39.5	50.2	44.9	79.8	27.0	22.6	24.8	49.0
75 percent of silks dead	8– 3	47.0	51.8	49.4	87.7	32.5	28.4	30.5	60.3
Blister to early milk stage	8–10	47.9	48.6	48.3	85.8	33.3	31.7	32.5	64.2
Milk stage	8–17	43.2	56.6	49.9	88.6	38.7	34.1	36.4	71.9
Soft dough stage	8–24	40.7	52.5	46.6	82.8	42.6	36.2	39.4	77.9
Hard dough stage	8–31	46.3	60.1	53.2	94.5	46.4	43.5	45.0	88.9
Nearly mature	9– 7	44.5	58.7	51.6	91.7	47.7	41.6	44.7	88.3

*1931 only.

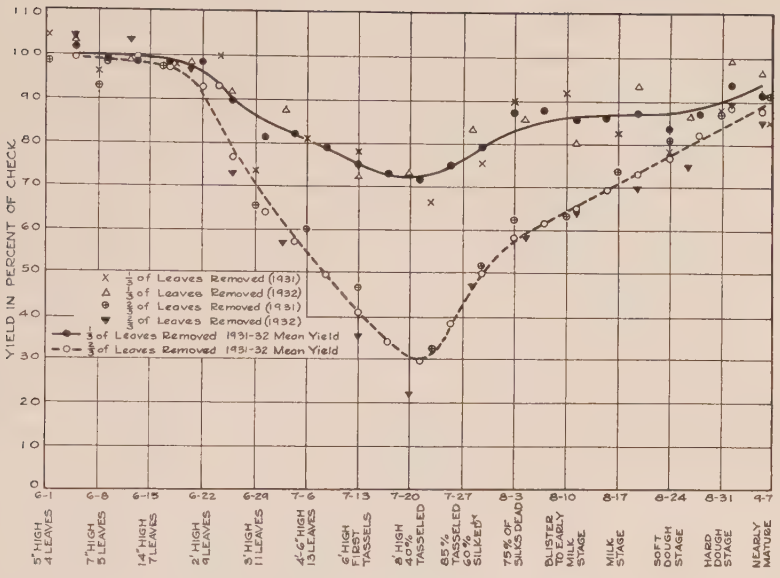

Fig. 15. Yield of corn in percentage of check from plants partly defoliated at various stages of development.

drop to a 30 percent yield for the two-thirds and a 70 percent yield for the one-third defoliated at the tasseling period. After the low point at the tasseling-silking period we find a rather abrupt rise for the next 2 weeks for both two-thirds and one third defoliated (already mentioned in the discussion on shredding) and then a more gradual rise back to 90 and 92 percent yield, respectively, at the nearly mature stage. While 2 years results do not give as smooth a curve as is desirable the annual yields show a fairly definite trend, especially since they correspond so well to the data on stripping and shredding. Again the results show close relation between percentage of leaf area removed and percentage decrease in yield at the critical stage of development. A comparison of the data in table 2 and fig. 15 shows that at the time when there was a sharp increase in the percentage of leaves unrolled (June 22) there was also a decided drop in yield for both one-third and two-thirds defoliation. On June 29 the average percentage of leaves unrolled had reached 45 percent. Therefore, removing one-third of the leaves removed approximately 15 percent of the total leaf area, and two-thirds removed about 30 percent of the leaf area. Figure 15 indicates that yields were reduced about 13 percent and 31 percent, respectively. This also agrees with other data on leaf removal in indicating that removing a small percentage of the leaves is relatively less harmful than removing a larger percentage.

RESULTS OF MINOR LEAF INJURIES

The method of conducting this phase of the investigation is described on page 21. In spite of the care used in inflicting the different types of injury the different season's results do not check well. The 1930 data are not included in the averages because of the severe drouth of that season.

Table 7 and fig. 16 give the data for the five types of leaf injury studies. "Cut alternate," "cut opposite" and "half shredded" show a maximum decrease in yield of 4.2, 10.3 and 10.7 percent, respectively. None shows a statistically significant decrease in yield. The "cut midrib" and "half leaf" treatments re-

TABLE 7. YIELDS IN PERCENTAGE OF CHECK FROM CORN PLANTS SUBJECTED TO FIVE TYPES OF LEAF INJURY AT VARIOUS STAGES OF DEVELOPMENT.

1930-1931-1932

Stage of maturity	Outer half of each leaf cut off	Outer half of each leaf shredded	Leaves cut to midrib on each side. Cut opposite	Leaves cut to midrib on each side. Not opposite	Midrib only cut
1930					
July 10—Corn 50 inches high, 10 leaves	66.0	102.4	96.7	99.6	90.9
July 30—90 percent tasseled, 15 percent silked	80.0	102.6	105.3	117.3	102.0
Aug. 18—Milk stage	91.5	99.7	100.7	105.7	100.0
1931					
July 8—56 inches high, 13 leaves	70.2	94.2	95.5	96.6	88.7
July 21—99 percent tasseled, 17 percent silked	53.2	83.0	88.6	96.8	80.5
Aug. 11—Early milk stage	92.9	95.1	99.2	93.9	93.6
1932					
July 5—56 inches high, 12 leaves	76.5	98.3	94.6	99.8	83.1
July 26—98 percent tasseled, 85 percent silked	81.2	95.6	90.7	94.8	80.1
Aug. 9—Early milk stage	80.3	90.9	96.9	98.1	90.1
Mean of 1931 and 1932					
July 6	73.4	96.3	90.2	98.2	85.9
July 24	67.2	89.3	89.7	95.8	80.3
Aug. 10	86.6	93.0	98.1	96.0	91.9
Mean yield of check	1930—21.2 bu.		1931—46.9 bu.		1932—64.5 bu.

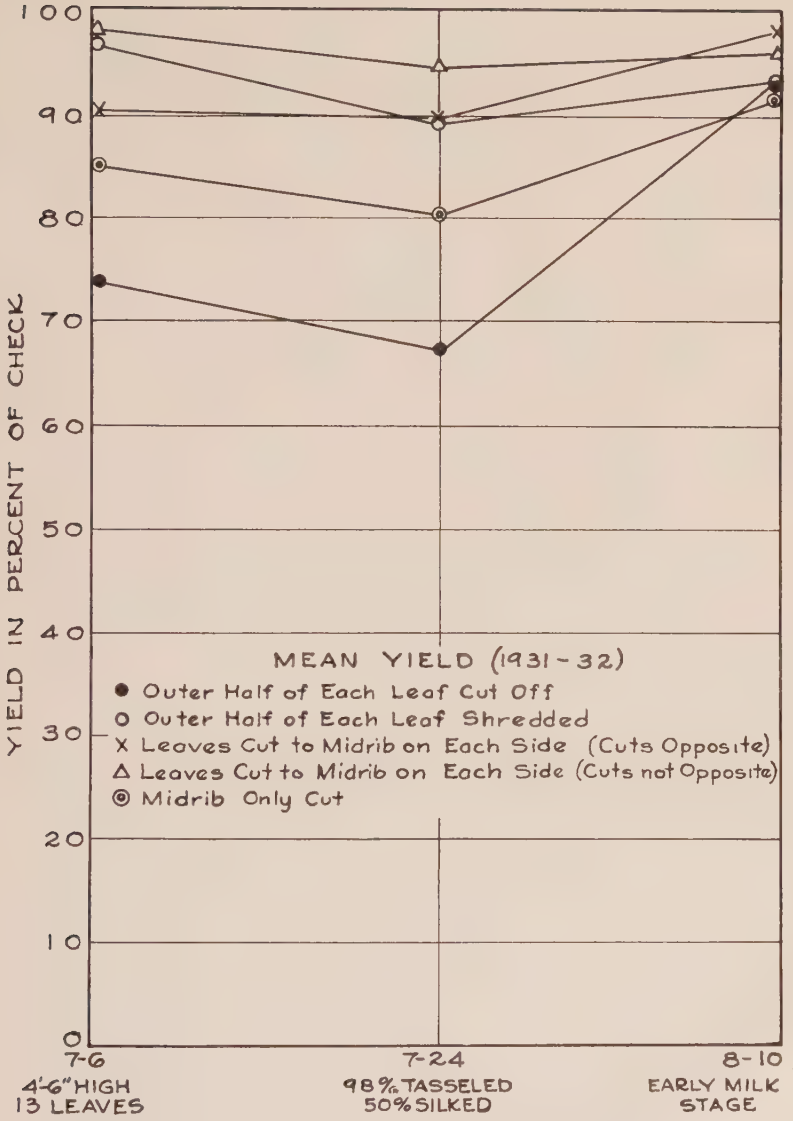

Fig. 16. Yield in percentage of check from corn plants subjected to five types of leaf injury at different stages of development.

duced the yield 19.7 and 32.8 percent, respectively. The reduction in yield with "cut midrib" was barely significant and with "half leaf," highly significant.

"Half leaf" was the only one of these five types of injury which was designed to reduce the leaf area of the plants. If carefully done it should have reduced the area 50 percent without injuring the remainder of the leaf or the stalks. These data indicate that this type of injury did not reduce yields in proportion to the percentage of leaves removed. The fact that none of the three stages when the injury was inflicted was the most critical is perhaps one reason for this. According to the data on shredding, where an attempt was made to remove 50 percent of the leaf area, the most critical stage was between the first two periods, or about July 12. The most critical time for one-third and two-thirds defoliation was about July 21. A comparison of the yields of half leaf removal with these others indicates that if the injury had been inflicted at a more critical stage the yield might have approached 50 percent of check. Another reason why removal of half of each leaf apparently was not as injurious, in proportion to leaf area removed as shredding, or as one-third or two-thirds defoliation, may have been a reduced interference with the translocation of plant food. The leaf area which remained was closest to the stalk thus reducing the distance which the elaborated plant food must travel. Also, the part of the leaf which remained was not bruised or torn, and there was less tendency for the remaining leaves to be injured by the wind or by firing.

The other four types of leaf injury were designed to interfere with photosynthesis without reducing the leaf area. This interference might be brought about in two ways, (a) retarding translocation and (b) changing the angle at which the rays of the sun struck the leaf. An attempt to retard translocation was made by cutting across the leaf from edge to midrib. The photosynthesis studies carried on in connection with this investigation (see p. 5 footnote 2) indicate that when translocation was interfered with by cutting across the leaf there was considerable accumulation of carbohydrates in the leaf during the day. The yields from the plots with leaves "cut opposite" and "cut alternate," while not significantly lower than check, nevertheless are lower and indicate that this interference had some depressing effect on the yield. Dungan (16) reported a 23 percent reduction in yield for this type of injury at the most critical period. "Cut opposite" should have been a more serious type of injury than "cut alternate" since it left only the midrib to bridge the gap between the outer half of the leaf and the inner half. The data indicate that this was true, though the yields were not significantly lower.

Shredding the outer half of the leaves and cutting the midrib caused the leaves to hang down so that the sun's rays did not strike them as directly as it did normal leaves. The photosynthesis studies indicated that this had little if any effect on rate of photosynthesis. This is also borne out in the "half shredded"

plots which did not show a significant reduction in yield. On the other hand the "cut midrib" showed the greatest reduction of any except "half leaves." This result is difficult to explain. The photosynthesis studies showed that cutting the midrib did not cause a significant decrease in rate of translocation. This would indicate that the midrib was not important as a conducting area. On the other hand the angle of exposure to the sun did not seem to be important, on the basis of carbohydrate accumulation in "drooping"[6] leaves (p. 5, footnote 2). This indicates that the angle of exposure should not be considered as the cause of the decreased yields. Hume and Franzke (29) obtained very slight reduction in yield from breaking the midrib. On the other hand, Dungan (16) found a 20 percent reduction with this type of injury.

EFFECT OF BRUISING STALKS AND EARS AND OF SHREDDING THE LEAVES

This phase of the investigation involves two distinct types of injury, (a) shredding of the leaves and (b) bruising of the stalks and ears. Both occur in natural hail damage in varying degrees of severity depending upon the type of storm. If the hail stones are small and are not driven by a hard wind, the leaf injury may amount almost to total stripping of the leaves while the stalks escape with only slight bruises. On the other hand, large hail stones driven by a high wind may bruise stalks and ears severely, but if the stones are not too numerous the leaves may escape with little injury. Early in the season there is no stalk injury with any type of storm because the plant has not yet developed a stalk. Late in the season, after the crop has nearly matured, hail may break the stalks so badly that most of the ears are on the ground, resulting in loss due to moldy ears. A storm at this same time, which caused only leaf injury, no matter how severe, would cause very little loss. Thus it is apparent that there is a great variation in types of damage by hail and that a study confined entirely to leaf injury would not solve the problem.

This phase of the investigation (the effect of bruising) was started in 1928 when bruising of stalks and ears was carried on in connection with the shredding of leaves. The results of the 1928 experiment indicated that stalk injury should be separated from leaf injury in order to determine the relative importance of each. In 1929 stalks and ears were bruised, but a combination of shredding and bruising of the same plants was not included. The two year's results showed the need of more complete data, and in

[6] "Drooping" leaves in the photosynthesis studies were split along the midrib so that one-half hung parallel to the stalk.

1930 both bruising only and a combination of bruising and shredding were included. The same type of experiment was carried on in 1931 and in 1932.

EFFECT OF BRUISING ONLY

In discussing the results, the 1928 and 1929 data are separated from the 1931 and 1932 data because they are not directly comparable. Table 8 and fig. 17 give the results of the 1928 and

TABLE 8. PERCENTAGE OF BROKEN STALKS AND YIELDS OF GRAIN FROM CORN PLANTS SHREDDED AND BRUISED. (1928-1929)

Stage of maturity	Date	Percent of broken stalks*	Leaves shredded and stalks bruised		Leaves shredded and ears bruised	
			Yield in		Yield in	
			Bushels per acre	Percent of check	Bushels per acre	Percent of check
			1928			
Check		6.0	49.0		49.0	
4 feet 6 inches high, 13 leaves	7–13	28.2	31.5	64.4		
30 percent tasseled	7–23	20.5	32.1	65.6		
70 percent tasseled, 35 percent silked	7–29	33.3	28.5	58.2	29.7	60.7
95 percent silked	8–10	34.1	39.8	81.3	37.9	77.4
Milk stage	8–21	35.0	44.4	90.7	39.8	81.3
Hard dough stage	9– 4	18.8	47.1	96.2	46.6	95.2
			1929			
			Stalks bruised		Ears bruised	
			Yield in		Yield in	
			Bushels per acre	Percent of check	Bushels per acre	Percent of check
Check		0.5	70.6		72.0	
5 feet high, 14 leaves	7–15	49.0	51.0	72.2		
7 feet high, 4 percent tasseled	7–22	38.0	61.4	86.5		
85 percent tasseled, 38 percent silked	7–29	59.0	49.9	70.7	57.3	79.6
75 percent of silks dead	8– 5	66.0	54.4	77.1	64.4	89.4
91 percent of silks dead	8–12	88.0	53.4	75.6	71.0	98.6
Early milk stage	8–19	81.0	62.6	88.7	66.9	92.9
Soft dough stage	8–26	68.0	71.0	100.6	72.3	100.4
Hard dough stage	9– 2	29.0	69.7	98.7	71.9	99.9
Nearly mature	9– 9	37.0	62.3	88.2	73.1	101.5

*These figures apply to the bruised rows only.

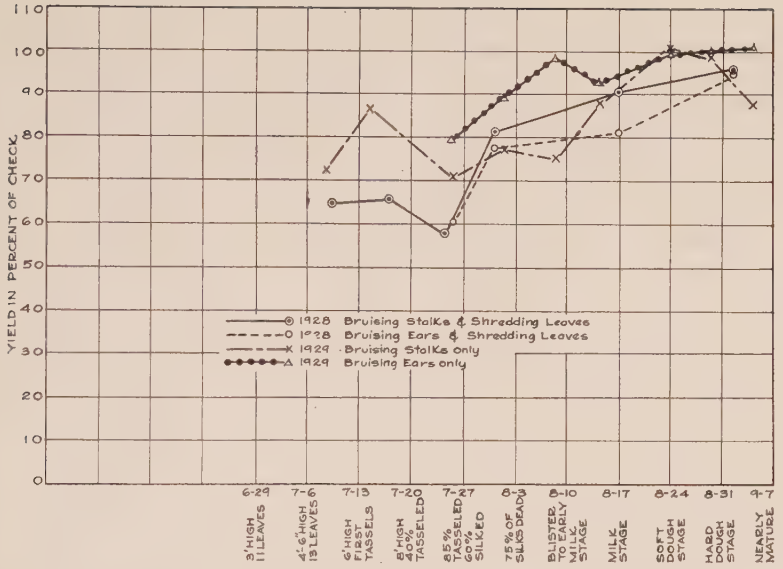

Fig. 17. Yield of corn in percentage of check from plants injured in different ways at various stages of development.

1929 experiments. In 1928 a reduction in yield of approximately 25 percent resulted from shredding during the tasseling-silking period (table 5). During this same period shredding the leaves and bruising the stalks caused a reduction in yield of about 42 percent. In the latter part of the season there is little difference in yield between the two types of injury.

The 1929 data do not permit the same comparison because during that year the leaves were shredded in one series and the stalks bruised in another, but there was no shredding and bruising of the same plants. Results of shredding in 1929 (fig. 14) show a maximum reduction in yield of 60 percent at the critical period, with a steady increase in yield from then to the end of the season. Bruising the stalks caused a 25 to 30 percent reduction in yield for 5 weeks during and after the tasseling-silking period. This indicates that bruising the stalks was about one-half as serious an injury as shredding the leaves in 1929. In other words, these 2 years' results indicated that bruising alone was more serious than bruising when in combination with shredding.

The 1931 and 1932 data permit a comparison of all three types of injury. Table 9 and figs. 18 and 19 give the results of shredding and bruising for 1931 and 1932. These data check fairly well with the results of 1928 and 1929. Bruising the stalks and ears, but with no shredding, caused a 20 percent reduction in

yield at the beginning of the period, increasing to 35 percent reduction at the critical period and gradually diminishing to a 5 percent injury at the nearly mature stage. The trend is very similar to that of the different types and degrees of leaf injury except that the critical stage seems to come later in the season. This can largely be accounted for by the fact that there is no ear injury until about July 27 when the ear shoots begin to appear.

An examination of the data on bruising the ears only, for 1929, shows a severe reduction for the first two weeks and only a slight reduction for the last 5 weeks. The 20 percent reduction on July 29 is probably excessive because of an unusual situation. This treatment was given at the stage when the ears were shooting and the silks were beginning to appear. Smut counts showed that in

TABLE 9. PERCENTAGES OF BROKEN STALKS AND DAMAGED KERNELS TOGETHER WITH YIELD OF GRAIN FROM CORN PLANTS SUBJECTED TO TWO TYPES OF INJURY AT VARIOUS STAGES OF DEVELOPMENT.

1931-1932

Mean stage of maturity	Mean date	1931		1932		Percent of damaged kernels	Mean yield	
		Percent of broken stalks	Yield per A. in bu.	Percent of broken stalks	Yield per A. in bu.		In bu. per A.	In percent of check
		Stalks and ears bruised						
Check		2.3	57.7	1.5	54.7	0.63	56.2	
56 inches high, 12 leaves	7– 6	4.9	49.3	14.1	44.3	0.15	46.8	83.3
6½ feet high, 10 percent tasseled	7–13	8.8	39.6	21.7	38.4	2.20	39.0	69.4
8 feet high, 70 percent tasseled	7–20	5.8	37.9	41.1	34.8	0.81	36.4	64.8
70 percent silked	7–27	22.1	39.5	47.5	34.0	2.23	36.8	65.5
70 percent of silks dead	8– 3	31.1	42.9	51.1	39.9	2.27	41.4	73.7
Early milk stage	8–10	40.1	46.4	56.1	35.5	2.75	41.0	73.0
Late milk stage	8–16	59.4	45.8	64.5	48.4	2.42	47.1	83.8
Soft dough stage	8–23	71.1	47.9	35.4	46.8	1.18	47.4	84.3
Hard dough stage	8–30	86.5	50.3	32.1	51.1	3.04	50.7	90.2
Nearly mature	9– 6	70.4	53.9	39.5	52.1	2.18	53.0	94.3
		Stalks and ears bruised and leaves shredded						
Check		3.0	55.2	2.0	54.9	0.51	55.1	
56 inches high, 12 leaves	7– 6	4.9	18.7	10.3	20.2	0.75	19.5	35.4
6½ feet high, 10 percent tasseled	7–13	8.5	11.4	16.0	14.0	2.03	12.7	23.0
8 feet high, 70 percent tasseled	7–20	8.5	19.4	18.7	21.1	1.74	20.3	36.8
70 percent silked	7–27	16.0	25.8	29.5	24.4	3.43	25.1	45.6
70 percent of silks dead	8– 3	21.9	32.6	25.5	28.1	3.06	30.4	55.2
Early milk stage	8–10	29.8	34.1	39.7	30.9	1.88	32.5	59.0
Late milk stage	8–16	48.1	41.2	43.4	37.6	1.05	39.4	71.5
Soft dough stage	8–23	63.8	45.7	26.4	47.0	2.11	46.4	84.2
Hard dough stage	8–30	76.9	51.1	41.7	47.8	2.52	49.5	89.8
Nearly mature	9– 6	74.5	51.5	45.0	48.5	0.88	50.0	90.7

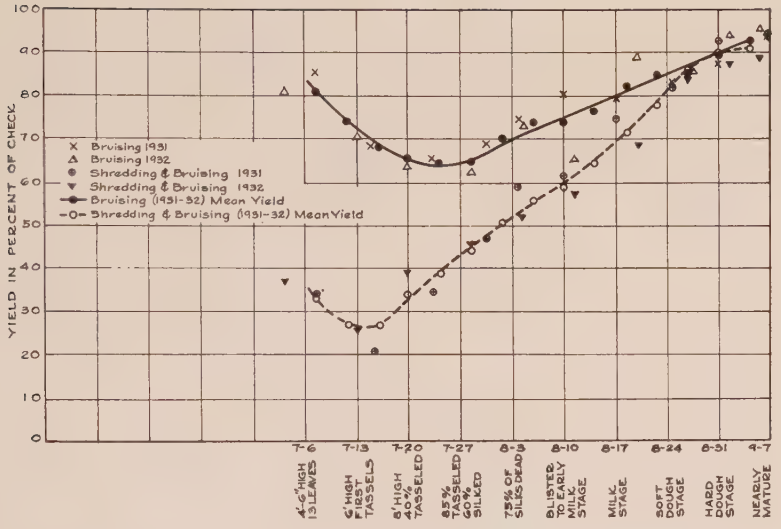

Fig. 18. Yield of corn, in percentage of check, from plants bruised only and bruised and shredded at various stages of development.

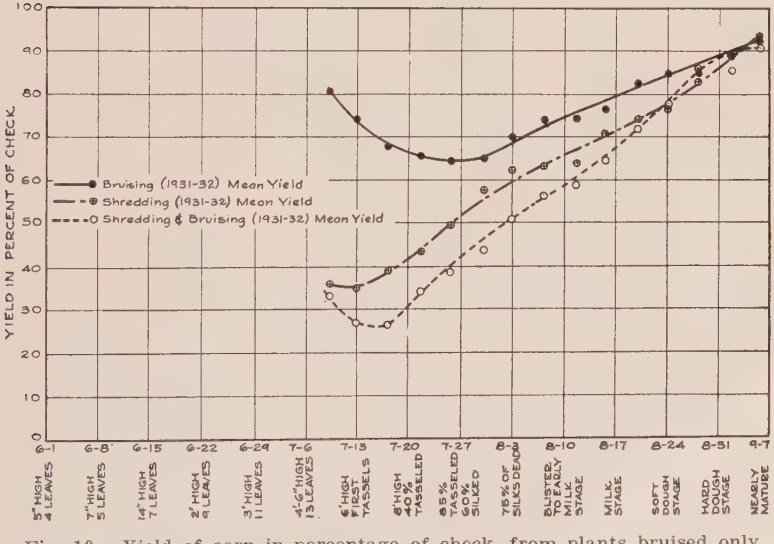

Fig. 19. Yield of corn in percentage of check, from plants bruised only, shredded only and bruised and shredded at various stages of development.

plots injured on this date, 18 percent of the ear shoots were infected with corn smut (*Ustilago zeae*) while the rows bruised a week later showed 7 percent of the ears infected. In plots treated at succeeding weekly intervals, the ear infection dropped to less than 1 percent, and adjoining check rows showed less than 1 percent. Infection evidently took place at the time of the injury because the developed smut masses had entirely replaced the ears, completely occupying the cavity within the husk.[7] These high smut infections were partly responsible for the 20 percent and 11 percent reductions in yield for the July 29 and Aug. 5 treatments. To agree with the other data on bruising perhaps a 10 to 12 percent reduction in yield for ear bruises at this critical stage (leaving out smut infection) would be a reasonable figure.

COMPARISON OF SHREDDING AND BRUISING

A study of fig. 19, which gives a direct comparison of (a) shredding only, (b) shredding and bruising, and (c) bruising only for 1931 and 1932, the only years when they could be compared directly, shows that while bruising caused a 36 percent reduction in yield at the critical period and shredding caused a 65 percent reduction the two combined caused less than 10 percent additional injury over shredding alone. An explanation of this result probably should be based on the fact that either shredding of leaves or bruising of stalks upsets the normal balance of the plant. With reduced leaf area a smaller conducting area is sufficient, while with a reduced conducting area the leaves are not able to synthesize carbohydrates efficiently owing to accumulations in the leaves. For this reason both types of injury on the same plant do not reduce yields by the same percentage that they do when each is on a different plant.

EFFECT OF BROKEN STALKS ON YIELD

The data on broken stalks in tables 8 and 9 indicate that stage of maturity was a much more important factor than broken stalks in determining the extent to which bruising affected yield. In fact, stage of maturity and weight of ear seemed to be rather important in determining the percentage of broken stalks. Very few of the stalks broke over on the day they were bruised; they gradually fell over as succeeding windy days, or increased weight of the ear, caused the stalks, weakened by the bruises, to break. An examination of the data shows that the percentage of broken stalks increased as the season advanced and the ears became heavier. This theory

[7] See reference on smut infection, p. 56.

is further confirmed by the fact that there was some tendency toward a larger percentage of broken stalks on the "bruised only" plots than on the "bruised and shredded" plots, where the ears were lighter because of the decreased photosynthetic area. Also, the percentage of broken stalks was less for the early season bruising, even though the stalks were more succulent and tender at this stage of maturity. Since there were no ears at this stage the stalks were able to maintain their position until the injury had partially healed and therefore did not break over as easily during later storms. It was observed that if plants injured in the tasseling stage did not break over within a few days after injury they were likely to stand until maturity. Later in the season, even though the stalks were much more mature and woody, and not as easily crushed by the blows of the "bruiser," there was a greater tendency for them to break at the time the injury was inflicted. Since there is no positive correlation between broken stalks and reduction in yield, the injury due to bruising was probably so severe that the breaking over of the stalk caused no additional damage.

The tendency of bruised stalks to become the prey of various types of molds and diseases is a point frequently in controversy in hail insurance adjusting. A discussion of this phase of the investigation is included later under smut infection.

DAMAGE TO EAR AND KERNEL

As previously discussed, the effect of striking each ear two blows did not seem to cause more than 10 percent additional decrease in yield over bruising the stalks only even at the critical stage. This reduction in yield was only 1 or 2 percent for the last few weeks of the growing season. The effect of striking the ear was very different at various stages of growth. The appearance of ears injured at successive stages of development may be seen in fig. 12. During the silking period a blow on the young shoot crushed the silks and prevented pollination so that the ear was frequently misshapen, but there did not seem to be much tendency for molds to develop. A little later, during the milk and soft dough stages, bruising the ear often brought about a condition favorable for the development of molds, especially when the husk was broken. These seemed to be superficial molds rather than corn diseases such as *Fusarium* and *Diplodia*. There usually was a small patch of blackened, moldy kernels which did not extend over a much greater area than that covered by the actual bruise. Ears completely infected with one or another of the common corn diseases did not occur any more frequently in the bruised plots than in the checks. Later in the

season, during the hard dough stage, usually a bruise merely crushed the kernels down into the cob without causing them to mold, although some moldy spots developed.

MARKET GRADE OF BRUISED CORN

Market grade determinations of the percentage of damaged kernels were made on 200 gram samples of shelled corn from the bruised plots in 1932. Table 9 includes the percentages of

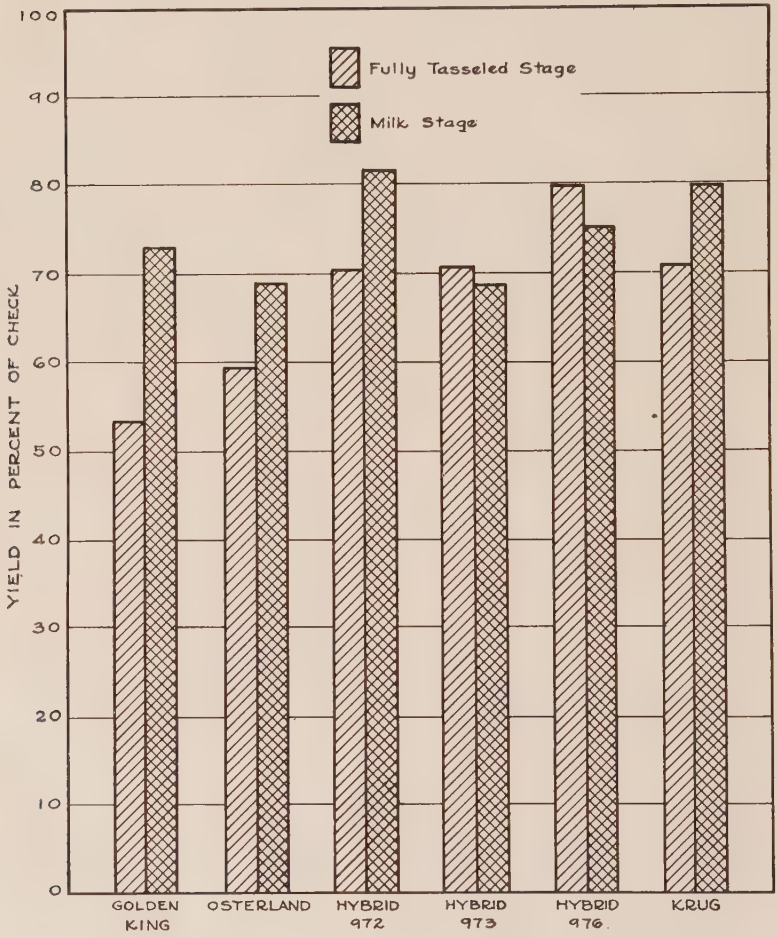

Fig. 20. Yield of corn, in percentage of check, from six varieties severely shredded at two stages of development, 1931 and 1932.

damaged kernels for the bruised and the bruised and shredded plots. These figures show that bruising increased the percentage of moldy kernels slightly. The Federal grain standards specify that No. 1 corn shall not have over 2 percent of damaged kernels. It is evident that the bruising would cause most of the corn from the bruised plots to grade no higher than No. 2 while that from the checks might have graded No. 1. Practically no corn, however, as marketed from the farm will grade better than No. 2 on account of moisture. Therefore the bruising did not lower the grade below that which the average farmer would receive for undamaged corn.

VARIETAL RESPONSE TO LEAF INJURY

Figure 20 gives the data on yields obtained from severe shredding of six varieties of corn. A statistical analysis of the yield data indicates that severe shredding caused no significant difference in reduction in yield of the six strains used in this experiment. While there were differences in the yields, particularly if the injury at each stage of maturity is considered separately, the differences are not consistent nor significant. They are probably due, in part at least, to the fact that the shredding was not done at exactly the same stage of maturity for each variety. For example, in 1931, Golden King yielded only 35 percent as much as the check when shredded in the tassel stage, whereas in 1932 it yielded as much as the others. The 1930 data are not included in the averages nor in the discussion. This is because drouth caused so many barren plants that the error is very high. The 1931 field notes made at the time of shredding, contain this statement regarding Golden King: "Probably shredded too early as compared with the other varieties." The yields obtained later indicated that this was the case. This result agrees with the results of the other leaf injury studies in which a period earlier than the full tassel stage had proved most critical.

A comparison of these variety data with those on shredding shows that the yield of these varieties was reduced about the same as the Steen Yellow Dent in the shredding experiments, at comparable stages of maturity.

The data on variety comparisons seem to justify the conclusion that there probably is no significant difference between the varieties used in their response to leaf injury. While the ranker growing, later varieties seem to be hurt a little less by leaf shredding, the difference may be due to failure to inflict the injury at exactly the same stage of maturity.

EFFECT OF DRY WEATHER ON THE YIELDS OF INJURED CORN

The results of the 1930 investigations have not been included with the other years because they were so unusual, as a result of the severe drouth of that season. Until the early part of July the rainfall was adequate, April, May and June each having a record of over 3 inches. The rainfall for the remainder of the season was as follows: July 4, 0.4 of an inch; July 21, 0.1, and in August, 0.91 of an inch coming in six scattered showers which barely moistened the surface; Sept. 14, 0.06 of an inch and Sept. 25 and 26, 2 inches, after the corn was mature. The above data show that there was no rain of any value to a growing crop after July 4. The plentiful moisture supply previously had started the corn off with a large top growth and a relatively deficient root growth so that it was particularly vulnerable to drouth during the time the ears were forming.

The results of the corn injury studies for 1930 are given in tables 7 and 10. No data on leaf shredding are included because the crop was a total failure. It will be noted that there are decided differences in yield between the checks of the different experiments. This is accounted for by the fact that the different experiments were located on different plots and in different fields which had been cropped differently the previous year and also were on different soil types. Since an extremely dry season accentuates differences in previous cropping, reserve moisture and soil conditions, it is logical that the different check yields should vary widely. Comparisons of yields should be made with check and not between experiments.

A study of the results obtained in 1930 shows that in several types of injury the yields were not reduced as much as they were in the other seasons. There was not much difference in the variety comparisons and in the minor types of leaf injury, although even these averaged slightly higher than those of the other seasons. The types of injury which involved considerable loss of leaves showed less reduction in yield than in the years with more normal rainfall. This was particularly noticeable on the plots located in college field where the drouth effect was most severe. These results are contrary to the generally accepted ideas of hail insurance adjusters and farmers who assume that hail injury in a dry season or when followed by a severe dry spell will be much more serious than in a normal season.

The fact that defoliation at certain periods in a dry season resulted in increased yields over the check plots might be explained in two ways. Partial defoliation early in the season, if done before transpiration had depleted the soil moisture, would result in a greater supply of moisture for the plant's later use. The other explanation might be based on the fact

TABLE 10. YIELD OF CORN FROM PLANTS INJURED IN VARIOUS WAYS IN A DRY SEASON. (1930)

Stage of maturity	Date	Total defoliation		1/3 defoliation		2/3 defoliation	
		Yield in		Yield in		Yield in	
		Bushels per acre	Percentage of check	Bushels per acre	Percentage of check	Bushels per acre	Percentage of check
Check		2.4		19.7		16.3	
4 inches high, 4 leaves	6– 3	2.7	110.7	20.0	101.5	26.0	159.3
7 inches high, 5 leaves	6–10	5.9	242.8	18.2	92.0	25.4	155.7
14 inches high, 7 leaves	6–17	6.4	264.6	15.8	80.2	26.9	164.8
24 inches high, 8 leaves	6–23	13.0	535.0	16.3	82.3	26.7	163.5
32 inches high, 9 leaves	6–30	11.9	488.9	16.0	81.0	23.7	145.6
45 inches high, 10 leaves	7– 7	8.0	329.2	12.8	65.0	16.2	99.6
5 feet high, 12 leaves	7–14	1.5	60.1	11.9	60.4	9.1	55.6
6½ feet high, 40 percent tasseled	7–21	0.0	0.0	11.0	55.7	7.7	47.0
90 percent tasseled, 15 percent silked	7–28	0.0	0.0	10.7	54.1	6.9	42.9
60 percent of silks dead	8– 4	0.0	0.0	11.8	59.5	7.4	45.4
Early milk stage	8–11	0.0	0.0	18.4	93.3	8.9	54.8
Late milk stage	8–18	1.9	77.0	14.7	74.4	11.7	71.5
Soft dough stage	8–25	1.9	77.0	17.2	86.9	12.3	75.7
Hard dough stage	9– 1	3.0	121.4	14.5	73.5	15.3	94.1
Nearly mature	9– 8	2.6	105.8	16.9	85.5	12.6	78.2

		Stalks and ears bruised			Stalks and ears bruised and leaves shredded		
			Yield in			Yield in	
		Percent of broken stalks	Bu. per acre	Percentage of check	Percent of broken stalks	Bu. per acre	Percentage of check
Check		2.7	24.4		2.7	24.4	
45 inches high, 10 leaves	7– 9	4.9	26.2	107.1	4.9	15.2	67.6
5 feet high, 12 leaves	7–16	8.8	24.4	100.0	8.5	8.1	33.0
6½ feet high, 40 percent tasseled	7–23	5.8	21.2	86.7	8.5	7.0	28.6
90 percent tasseled, 15 percent silked	7–29	22.1	17.6	71.8	16.0	10.6	43.2
60 percent of silks dead	8– 5	31.1	19.0	77.9	21.9	11.1	45.3
Early milk stage	8–11	40.0	19.5	79.9	29.8	14.6	59.9
Late milk stage	8–19	59.4	21.6	88.5	48.1	17.8	72.6
Soft dough stage	8–25	71.1	22.8	93.1	63.8	20.9	85.6
Hard dough stage	9– 1	86.5	20.6	84.5	76.9	21.3	86.9
Nearly mature	9– 8	70.4	23.6	96.4	74.5	24.3	99.3

that if dry weather limited a normal 60 bushel yield to 20 bushels the normal leaf area of the plants would not be needed. Perhaps 50 percent of the area or less could manufacture enough carbohydrates to produce the 20 bushels. Under such conditions

removal of part of the leaves would not reduce the yield as much, in comparison with check plants, as this same removal would in a normal season.

The data in table 10 indicate that this is what happened when all the leaves were removed during the latter part of June, 1930. With drouth conditions so severe that the yield of the check rows was only 2.4 bushels per acre, the plots having all unrolled leaves removed on June 23 yielded 13 bushels and on June 30, 11.9 bushels per acre. This was at a period when about 50 percent of the leaves were unrolled, and it was also just at the end of a period of plentiful rainfall and the beginning of a severe drouth. The check rows, which developed all their leaves, soon exhausted the soil moisture so that practically no crop was produced. On the other hand the rows with half their normal leaf area were saving soil moisture, because of reduced transpiration, and were enabled to produce part of a crop. They probably had sufficient leaf area to develop as much of a crop as the dry conditions permitted.

Results of removing two-thirds of the leaves were very similar to total leaf removal except that they were not so pronounced. Yields of the injured plots remained consistently higher than the check rows up until the June 30 treatments. Removal of two-thirds of the leaves obviously would not reduce transpiration as much as total leaf removal. During the critical tasseling-silking period yields were reduced to between 40 and 50 percent, while in 1931 and 1932 they were reduced to 30 percent of a normal crop for the same period.

Removing one-third of the leaves in 1930 resulted in a much greater proportionate reduction in yield than two-thirds defoliation, and this treatment at the critical period was somewhat more injurious than the same treatment in 1931 and 1932. Bruising the stalks was somewhat less harmful in 1930. But bruising and shredding, with a 50 percent reduction in leaf area (and transpiring area), reduced yields less in 1930 than in 1931 and 1932, another indication that the saving of soil moisture was more important than having a maximum photosynthetic area.

EFFECT OF INJURY ON TIME OF MATURITY

In the adjustment of hail losses one of the factors frequently in controversy is the question of delayed maturity as a result of early storms. A severe storm occurring before the corn is a foot high may cut a large proportion of the plants off near the surface, destroying nearly all the leaves. Yet with favorable weather, recovery will be rapid so that in 2 or 3 weeks the field appears nearly normal. The farmer asks for heavy dam-

ages, claiming that the corn is so delayed in maturity that he is in danger of frost damage in the fall. The question of delay in maturity as a result of early injury was considered in this investigation and an attempt made to determine how much the crop was delayed and what effect this might have on the value of the crop produced.

A common method of determining whether one strain of corn is earlier than another is to compare the moisture content at harvest. The strain having the least moisture is assumed to be the earlier. This method, however, does not fully answer the question involved in these investigations. The yield was reduced by the injury inflicted, but how much more it might have been reduced by an abnormally short season could not be determined because corn matured reasonably well each year during which the investigation was conducted. If a method could be devised by which a delay in maturity could be determined with reasonable accuracy it would be of value in hail damage settlements.

It is generally assumed by investigators that the time of tasseling and silking is a good index of comparative earliness in strains of corn. Olson (45) states that "tasseling and silking appear to furnish a reliable basis for comparing varieties or strains of corn as to earliness." Meyers (38) suggests that the average date of silking is a good measure of comparative maturity. Alberts (1), working with several varieties of dent corn which varied widely in maturity, found very little difference in the time from silking to denting for the different varieties. It was about 40 days, on the average, being even less for late varieties than for early. On the other hand, the time from planting to silking varied greatly in different varieties. He also found that delayed planting did not proportionately delay silking. The time from planting to silking was less for corn planted late than for that planted early. These investigations indicate that if the difference in time of silking between two plots of corn could be accurately determined it would give a good indication of the comparative dates of maturity.

The Ohio Station (43) reported a study in which corn was harvested at different stages of maturity from early dough to 1 week after maturity. Yields increased steadily as follows: Early dough 43.4 bushels, dough 50.3 bushels, late dough 55.7 bushels, hard dough 60.3 bushels, mature 62.6 bushels and 1 week later 63.3 bushels. These data indicate that maturity is an important factor in maximum yields, a fact which yield tests support. Robinson (53) in a comparison of different varieties planted at different dates found a decided relationship between percentage of moisture at harvest and yield per acre.

He had, however, rather large differences in moisture between corn planted at 15-day intervals. Whether a 2 percent or 3 percent difference in moisture would give a significant difference in yield or indicate a significant difference in maturity is difficult to determine.

Both percentage of moisture at harvest and time of tasseling and silking were used in this investigation since both might have value in determining whether maturity had been delayed by injury. Moisture content at harvest was computed on each type of injury for each weekly stage of maturity. In addition, notes were taken on the time of tasseling and silking on the injured plots and the check plots. These data are presented in table 11. Meyer's (38) work showed that approximately one day should be allowed for each 10 percent difference in percentage of plants silked when comparing the maturity of two different plots. Alberts' (1) data indicated that time of silking was a rather accurate measure of time of maturity. The column in table 11 headed "average number of days delay in maturity based on time of silking" was computed by taking the difference in percentage of silking between the checks and the injured plots and considering each 10 percent difference to be the equivalent of 1 day difference in maturity. This probably is not a very accurate measure of delay in maturity but no better method was available. The differences in moisture content certainly indicated some delay in maturity, or "setback," as it is frequently called. Just what this delay amounted to when measured in days was difficult to determine.

According to this scheme of determining delay in maturity, leaf shredding delayed maturity from 0.5 days to 2.3 days, depending on the time of injury. Stripping, which meant complete destruction of the above ground parts of the plant up until about June 15, delayed maturity from 1.8 days to 5.5 days depending on the time of injury. As already mentioned, the Ohio Station found differences of about 5 bushels per acre in corn harvested at the different stages of maturity. It seems reasonable to assume that in a normal season with corn maturing rather rapidly, a 2- to 5-day delay in maturity might result in a 2- to 5-bushel decrease in yield if frost came before the injured corn was mature. The data on stripping would seem to indicate that the corn plant is producing additional yield faster than 1 bushel per acre per day during the latter part of the season. Alberts' work showed that corn took 40 days from silking to mature. This also indicates a greater increase than a bushel per acre per day during the last 2 weeks before maturity.

THE RELATION OF INJURY TO CORN SMUT INFECTION

Many farmers believe that any injury to the plant will increase the amount of infection by corn smut (*Ustilago zeae*), and this belief is frequently an important factor in a hail damage settlement, the farmer claiming additional losses because of the increased smut infection which he is certain will result from the plant injury.

REVIEW OF THE LITERATURE ON CORN SMUT INFECTION

Brefeld (5), after a series of experiments concluded that the smut sporidia are short lived; also that the infection is local, not spreading from the point of infection to other parts through the plant tissue. Clinton (6) found it difficult to infect young corn plants, either normal or mutilated. He obtained, however, a very high degree of infection on young mutilated ears and tassels and concludes that the large quantity of sugar being

TABLE 11. ESTIMATES OF RETARDATION IN MATURITY RESULTING FROM INJURIES AT DIFFERENT STAGES IN DEVELOPMENT OF THE CORN PLANT.

Approximate date of injury and stage of maturity when injured	1928 Percentage silked on 8/1	1929 Percentage silked on 7/30	1931* Percentage silked on 7/29	1932 Percentage silked on 7-22	Average number of days delay in maturity based on time of silking	Average moisture content
	Stripped plots					
Mean of checks	90	46	80	45		29.4
6/1, 5 inches high, 4 leaves		6	65	6	3.1	37.1
6/8, 7 inches high, 5 leaves	20	17	70	0	3.1	33.8
6/15, 14 inches high, 7 leaves		19		0	3.9	34.7
6/22, 2 feet high, 9 leaves	2	6		9	1.8	32.5
					5.5	
6/29, 3 feet high, 11 leaves		9		0		33.3
7/6, 4 feet high, 13 leaves	40			0	4.1	31.4
7/13, 6 feet high, first tassels					4.8	
	Shredded plots					
Mean of checks	90	55	80	27		27.6
6/1, 5 inches high, 4 leaves		39	80	36	0.5	29.2
6/8, 7 inches high, 5 leaves	40	21	75	38	2.3	32.1
6/15, 14 inches high, 7 leaves		33	Same	40	1.1	28.6
6/22, 2 feet high, 9 leaves	60	30	as	28	1.8	29.7
6/29, 3 feet high, 11 leaves		31	Check	19	1.6	28.6
7/6, 4 feet high, 13 leaves				32	0.5	28.9
7/13, 6 feet high, first tassels	55					29.0

*Notes on maturity obtained too late to be satisfactory.

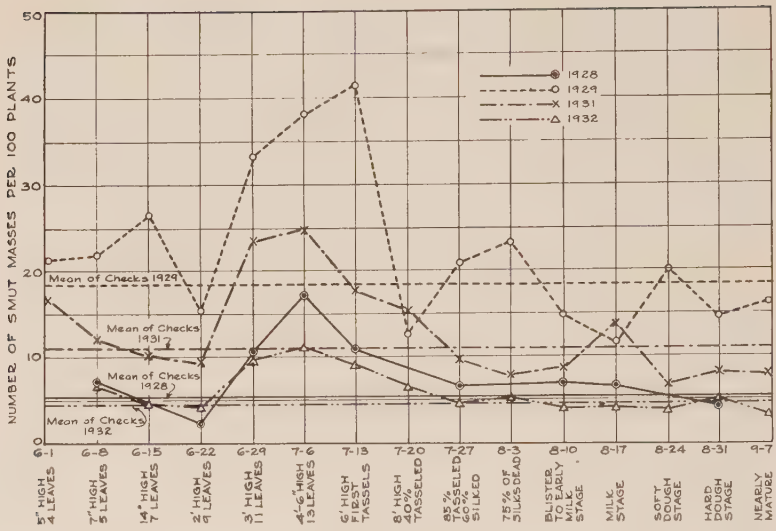

Fig. 21. Number of smut masses per 100 plants, by season and by stage of development for checks and mean of all types of injury.

carried to the rapidly developing parts furnishes an excellent medium in which the spores may germinate. Hitchcock and Norton (28), as well as Brefeld (5), found that corn 2 to 3 feet high was most susceptible.

Piemeisel (47) found that injury tended to increase the chances for infection, but was not necessary for successful infection. He states that "vigorously growing plants, between 2 and 3 feet high, are most susceptible to smut attacks."

Several investigators have attempted to show a relation between weather and smut infection. Selby and Hickman (55), Potter and Melchers (49 and 50), and Pammel and Stewart (46) all hold that dry weather rather than wet is most favorable for corn smut infection. On the other hand, Arthur and Stuart (4), MacMillan (37) and Piemeisel (47) hold that wet weather is more favorable. Coffman, Tisdale and Brandon (7) state that smut varies with different seasons.

MacMillon (37) studied smut infection in a region in Colorado which had suffered a severe hail storm on July 29, 1918. On Aug. 14 he made several counts and found an average of 19 percent infection in the hailed region and 1 percent in corn fields outside of the hailed region. The smut boils were remarkably uniform in size and were apparently all the same age. They all occurred in the axils of the leaves and none was found in wounds or bruises. Davis (9) was able to cause development of smut masses, later in the season, by artificial inoculation

before the plants were 30 days old but was unable to produce smut masses by inoculation after that time. He holds that infection takes place only in meristematic tissue, so could take place only while the plants are small or else within the husk cavity or nodal bud tissue while in process of development. He believes that this early infection may not express itself in a developed smut mass unless an injury or unfavorable growing conditions upset the normal balance of the plant.

Platz (48) discussing the matter of increased susceptibility due to injury states: "Mutilating the plants before dusting them with chlamydospores or spraying them with a suspension of sporidia did not induce infection." Artificial infection in the field in 1927 was not very successful although he readily infected young ears by dropping the suspension into the distal ends of the ear shoots.

Several instances of decided resistance or susceptibility among inbred lines and hybrids have been reported. Jones (32), Hayes et al (25), Garber and Quisenberry (21), and Coffman, Tisdale and Brandon (7) found significant differences in smut resistance in inbred strains of maize.

The effect of smut on yield has been investigated by Garber and Hoover (22, 23) who found no effect of smut on yield of adapted varieties except as it caused barrenness. Jorgenson (33) made paired comparisons in selfed and F_1 lines, using a smutted and a smut free plant for each pair and obtained a 39 and 50 percent reduction in yield, respectively, from the smutted plants. Immer and Christenson (30) using the same method found differences ranging from 7 to 94 percent due to smut.

SMUT INFECTION IN INJURED PLANTS

A summary of the foregoing literature on corn smut seems to justify the conclusion that smut infection probably occurs early in the development of the corn plant in rapidly developing meristematic tissue and that the later development of smut masses might be influenced by weather, injury, or variety, but that it would be very difficult, in many instances at least, to prove that an unusual amount of smut in a particular field was due to any one of these factors.

The data on smut infection are given in tables 12 and 13, and fig. 21. Counts were made each season about a month after the date of the last injury, in order that any infection at the time of the later injuries would have had time to show up. The counts were made on the basis of total number of smut masses rather than on number of infected plants. Thus any infection later in the season, due to injury on plants already infected, would be taken

into consideration. The data show that there was an increase in smut on the plants injured between June 29 and July 13, or for the 2 weeks just preceding the appearance of the tassels. Before and after that period there were about the same number of smut masses on the injured plants as on the checks. There is a period preceding tasseling when the corn grows rapidly. The physiologic balance of the plant apparently is more easily disturbed during this period and injuries increase the chances for previous smut infection to manifest itself. As has been discussed previously, Clinton, Brefeld, Hitchcock and Norton, Piemeisel, Davis and Platz all reported that a susceptible period occurred early in the development of the corn plant and perhaps the injuries inflicted during the rapidly growing period preceding the appearance of tassels caused sufficient disturbance in the plants' physiology to bring about an increase in smut masses.

The data in table 12, which show the effect of type of injury on smut infection, indicate that there were no significant differences in smut infection because of leaf injury as compared with stalk bruises. The fact that smut infection on shredded and stripped plants runs slightly higher than on bruised plants is accounted for by the fact that the latter type of injury was not started until the critical point in the growth of the plant was nearly past.

As has already been mentioned in the discussion on bruising of stalks and ears, in 1929 the percentage of ear smut on the rows where the ears were bruised when the silks were just appearing (July 29) was increased to 18 percent and a week later to 7 percent. This increase of ear smut was evidently due to bruising the ears since the check rows adjoining had less than 1 percent of ear smut, and the ear smut on rows injured at succeeding weekly periods was 1 percent. This result agrees with that reported by Clinton (6), who secured a high degree of ear infection on bruised ear shoots. There was no appreciable increase in ear smut on the bruised plots in any of the other seasons during the progress of this experiment. Evidently

TABLE 12. NUMBER OF SMUT MASSES PER 100 PLANTS BY TYPE OF INJURY. (MEAN OF ALL DATES OF INJURY.)

Type of injury	1928	1929	1931	1932	Mean
Mean of all checks	5.4	18.5	11.2	4.5	9.9
Stripped	9.9	25.0	11.5	5.0	12.9
Shredded	4.9	22.0	15.3	8.3	12.6
One-third of leaves removed				4.9	
Two-thirds of leaves removed				5.0	
Stalks and ears bruised	8.4	14.0	10.0	5.6	9.5
Stalks and ears bruised and leaves shredded	10.5		12.8	5.0	

TABLE 13. NUMBER OF SMUT MASSES PER 100 PLANTS BY SEASON AND BY STAGE OF MATURITY.

(All types of injury averaged.)

Average stage of maturity when injured	1928	1929	1931	1932	Mean of all years	Mean of '29, '31 and '32
Mean of all checks	5.4	18.5	11.2	4.5	9.9	11.4
June 1—5″ high, 4 leaves		21.2	16.7			
June 8—7″ high, 5 leaves	7.0	22.0	12.3	6.9	12.1	13.7
June 15—14″ high, 7 leaves		26.4	10.3	4.5		13.7
June 22—2′ high, 9 leaves	2.3	15.3	9.5	4.2	7.8	9.7
June 29—3′ high, 11 leaves	10.7	33.2	23.5	9.8	19.3	22.2
July 6—4½′ high, 13 leaves	17.0	38.2	24.7	11.0	22.7	24.6
July 13—6′ high, first tassels	10.9	41.4	17.4	9.2	19.8	22.7
July 20—8′ high, 40% tasseled		12.4	15.1	6.4		11.3
July 27—85% tasseled, 60% silked	6.9	20.7	9.7	4.5	10.5	11.6
Aug. 3—75% of silks dead		23.2	7.9	5.2		12.4
Aug. 10—Blister to early milk stage	7.0	14.9	8.7	4.1	8.7	9.2
Aug. 17—Milk stage	6.5	11.7	13.5	4.0	8.9	9.7
Aug. 24—Soft dough stage		20.0	6.9	3.7		10.2
Aug. 31—Hard dough stage	4.3	14.5	8.3	4.7	8.0	9.2
Sept. 7—Nearly mature		16.1	7.9	3.2		9.1

the decided increase in infection on the bruised ears in 1929 was due to the exposure of meristematic tissue of the young ear at a period when smut spores were abundant and the weather was favorable for their dissemination and germination. This combination did not occur in the other seasons, and as a result there was no increase in smut from ear injury in these years.

While no systematic study of other corn diseases was carried out, careful observations were made each season, especially on bruised stalks and ears. At harvest all moldy ears were sorted out and a record made of the proportion of good ears and moldy ears in all plots. These observations and counts indicated that there was no appreciable increase in the common corn diseases, such as Diplodia and Basisporium.

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